

SCALE UP THE PROCESS

The realization of
industrial housing

Tessa Meij





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Master thesis

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Preface

Hereby I proudly present my graduation thesis on the realisation of industrialisation housing, which brings me to the end of my study in Delft. This graduation thesis is the result of a one-year research process and is the final product of the Graduation Laboratory of the master track Management in the Built Environment of the Faculty of Architecture and the Built Environment at the Delft University of Technology. The research process started in September 2020 and lasts until the 1st of July 2021, the day that this graduation research will be presented and that I will graduate from this university.

Throughout my studies, I have always been fascinated by our built environment and what we are capable of. At the same time, I have been very aware that our built environment must respond to today's social problem caused by globalisation. In the coming years, we will have to face these challenges in our built environment. With both my professional and housing career soon ahead of me, it has become increasingly apparent that housing is one of the biggest problems in our built environment. Due to the shortages of houses, a roof over your head is no longer as obvious as it should be. With everything we are capable of in our built environment, we should be able to provide an answer for this problem. This was the motivation to research one of the possible answers, the industrialisation of housing. During my research, my fascination for this subject has only increased; this made it a very inspirational and enjoyable process.

This inspiration and joy would not be possible without people during the process. First, I would like to thank my supervisors Peter Boelhouwer and Gerard van Bortel from the Technical University of Delft, for advising me, sharing their knowledge, and challenging me during the process. I enjoyed the informative but also very pleasant conversations we had, in which your way of guiding perfectly matched my expectations. Secondly, I would like to thank my internship mentor, Ramon Zijderveld, for the new insights and enthusiasm. In addition, with your help, I have had the opportunity to gain many unique experiences within Heijmans opportunities. Furthermore, I would like to thank all other involved experts and interviewees that inspired me and gave me the chance to validate my results and take this research to a higher level. It was interesting to learn from your experience, and I very much enjoyed the discussions and knowledge exchange. It was nice to see how much enthusiasm there was for my research and how many people were willing to engage in the conversation.

Finally, I would like to thank my family, boyfriend, housemates, and friends on a personal note. At first, those who made my student life an incredible and unforgettable period of my life. In addition, everyone who helped me during my graduation period. It was nice to see that the subject also started to live among you, so that you alerted me to headlines and news items about industrial housing. And of course, your help with a coffee, a walk, fun and distraction or just a listening ear was indispensable!

In the years to come, I look forward to using the experience I have gained to contribute to these challenges in our built environment, of which this research is a first contribution.

Enjoy reading!

Tessa Meij

Delft, Juny 2021

Abstract

Housing is a topic that concerns everyone, but the attention for housing has grown in the last years. There is an enormous urge for sufficient and affordable housing in a world where we cannot ignore globalisation. The market is looking for a way to answer this demand for affordable housing. Industrial housing is one of the answers.

Industrial housing can provide an affordable, fast, and quality solution against the tremendous pressure on the housing market. It is an industrialised process to create efficient, flexible, and affordable housing on a large scale and at the same time offer a sustainable circular solution. Multiple constructors developed a product, but despite these benefits and the products that are already available, most of the new houses are still constructed in a traditional way. The reason for this is a lack of knowledge about the industrial housing product, hesitation of the market and lack of cooperation between actors. This research analyses industrial housing and the opportunities and barriers to scale up the production of industrial housing. The goal of this research is to identify the improvements in the process that are needed to scale up the production. To identify the required improvements needed, an understanding of industrial housing, the production process, and the actors involved must be gained. Therefore, in this research, a literature study has been carried out that describes the development of housing in relation to industrial housing, defines the scope of this research, and gives insight into the process with the involved actors. The literature study is complemented with an empirical study, in which interviews have been conducted to get findings from practice. The empirical research focuses on the industrial product, process, and project. This project was explored as a case study on the use of a building flow. The identified barriers and opportunities of the theoretical and empirical study were compared to define recommendations in the synthesis. An expert panel of experts in industrial housing was held to validate and discuss the recommendations. The main recommended adaptations include innovations and digitalisation of the product, national guidance and regulations from the public parties using a long-term vision, the clients in industrial projects must start thinking in terms of the product, the function of a building flow and the transparent exchange of knowledge that is needed to create cultural and organisational change.

Key terms: Industrial Housing, Housing Shortages, Housing Market, Production Process, Barriers and Opportunities

Executive summary

Introduction

The Dutch housing market is under tremendous with an increase in households and a low production capacity over the last. It is estimated that the housing demand will increase by 839.000 until 2035 (ABF Research, 2018). A recent action plan published in cooperation with 34 organisations addresses the need to realise 1.000.000 houses in the next ten years (*Actieagenda Wonen*, 2021). One of the solutions to solve this production capacity problem is the large-scale use of industrial housing. Multiple building companies developed prefabricated or modular products to answer the housing shortages to create efficient, flexible, and affordable housing on a large scale. Higher and faster production can be reached by moving the construction to a factory and only assemble the houses on-site at the location (Huijbregts, 2020). The benefit of industrial housing includes sustainability and circularity with a more efficient process and reduces the risks.

Despite these benefits and the proven industrial housing methods and facilities that are available, most of the new houses are still constructed in a traditional way. The first problem is that there is much confusion about the concept of industrial housing. Many think that we are already industrialising by using prefabricated materials (Van de Groep, 2020). However, prefab has been the standard for at least 50 years, and industrialisation goes far beyond this. The offsite production of separated parts is not the innovation we need for industrial housing. For this transition, we talk about offsite production on a large scale based on a production chain. To initiate this production chain, the constructor must invest in the construction of a factory. A factory means a high one-time investment that is therefore only reserved for the larger organisations and only becomes profitable with a minimum production. This large investment makes companies hesitant to invest and need to see a potential for a sustainable business development (McKinsey & Company, 2019) reducing order lead time and creating variety with limited resources. In the construction industry, the implementation of modularity has been limited to off-site production (OSP). This hesitation of these companies is the second and even more significant problem for a successful transition.

Besides constructors that develop a product, multiple other actors are involved in the process, for example, housing cooperation, investors, and public parties. Every actor in the process must act to make the transition; they all must change their way of working and need to cooperate. Multiple constructors developed a product, but they face the issue that the production process is not ready for upscaling. To scale up a structural cooperation is needed, but different barriers hinder this transition towards the optimal use of the production process. This is the third problem.

This research analyses the topic of industrial housing and the opportunities and barriers to scale up the production with adaptations in the process. The main research question of this research is as follows: *What adaptations are needed to scale up the Dutch production of industrial housing?*

Sub-questions have been formulated to answer the main question:

- Q1 - What is industrial housing?
- Q2 - What are the benefits of industrial housing?
- Q3 - How are different actors currently involved in the process?
- Q4 - How does the current production process of traditional and industrial housing work?
- Q5 - What are the opportunities and barriers for industrial housing?
- Q6 - How can the opportunities be optimised, and the barriers overcome?

Research method

The process is divided into three parts, 'theoretical', 'empirical' and 'synthesis'. The sub-question that is answered in a section is placed in the second row. Underneath the method, the output that relates to a phase can be found.

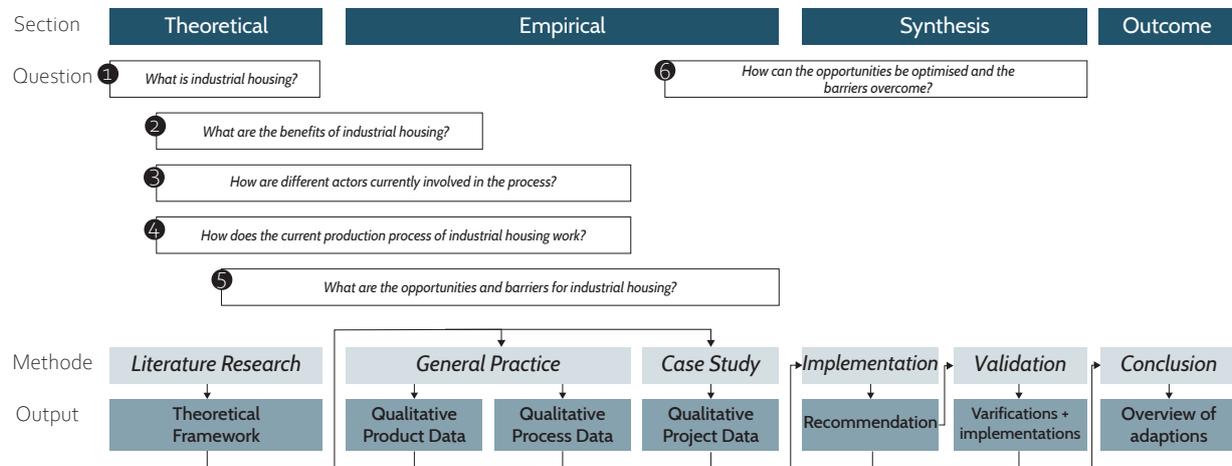


Figure i - Research method (own illustration)

Each method relates to one or two techniques. The main techniques for this research are reviews, interviews, and analysis.

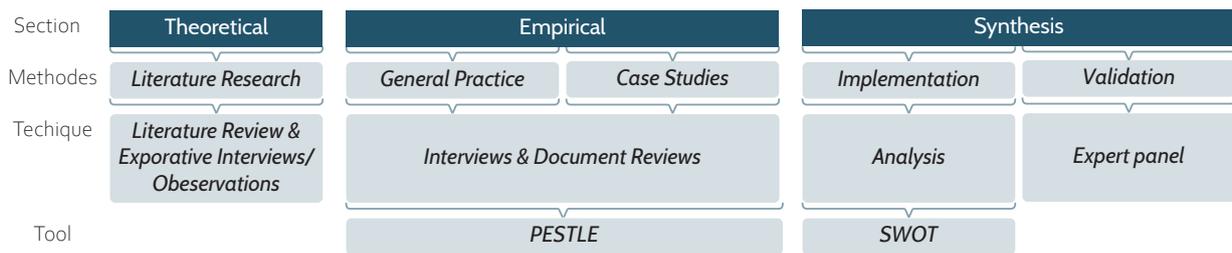


Figure ii - Methods and Techniques (own illustration)

The first phase is focused on the literature to get familiar with the subject of industrial housing. This is done with a literature review, explorative interviews, and observations in the field. The empirical research is the second phase of this research and is divided into two parts of qualitative research, 'general practice' and 'case studies'. The general practice section is an analysis of the barriers and opportunities experienced by the actors involved in the process. The actors involved in the process are constructors of the different products, housing corporations, developers, suppliers, public parties, and residents. A total of 21 interviews was conducted within 15 different organisations. For the case study the building flow in the urban area of Eindhoven was selected. This building flow is an initiative that stimulates corporations and actors in the construction chain to work differently (Aedes, 2020). In the synthesis, the results of the research are analysed, validated, and implemented. The result of this chapter are the recommendations with the expert panel's comments, which lead to the final conclusions.

Research findings

The industrialisation of housing is a change in the building process towards a more mechanical and automated production. This process includes prefabricated parts or modular components and the use of digitalisation with robotisation. The connection between the different labels of development and overlap in industrialisation is illustrated in Figure iii. The result of combining these developments lead to an industrial house. This industrial house is manufactured using a digitised offsite fabrication method to produce standardised houses. The result of this fabrication is not a concept but a final product.

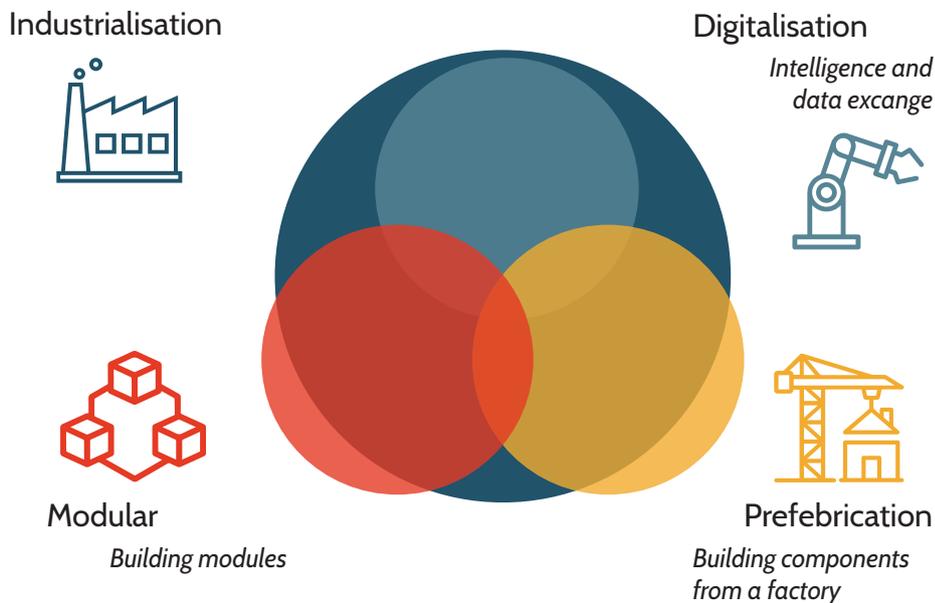


Figure iii - Connection labels of development

The market sees industrial housing as the industrialisation of the product and the process. The role of a factory-based approach (repeating, automating, robotizing, conditional circumstances) and innovation in the product (standardized variation, digitalization) is essential.

For industrial housing, it can be discussed:

- If the factory is a production line, an assembly line or can it be both.
- If the product consists of 2D, 3D-modules or a combination.
- If it is conceptual housing or industrial housing.
- What the target group is.
- What the location is.
- If it is a stacked, unstacked product or both.

Industrial housing could answer the housing market shortages, but there are more reasons why industrial housing should be the answer to housing in the Netherlands. The benefits of industrial houses in the product and process have an impact on the five categories: quality, time, cost, risk and environment.

- I. Quality: The quality of the product improves; this includes a better control and consistency of the quality because products are factory-made
- II. Time: The production process time is reduced because the construction time is shorter, and the process time is optimised
- III. Cost: The optimised production process is more efficient in time and resources; this leads to a cost reduction of the product and the process.
- IV. Risk: Risk in the process is reduced due to the optimisation of the process and the fact that the product is constructed in a factory.
- V. Environment: The process and the product are better for the environment; this includes sustainability, reduction of waste, circularity and the use of a material passport

To identify opportunities and barriers and provide adaptations to overcome them, the actors and the process is analysed. The figure below gives provides an overview that creates an understanding of how actors are involved and the process of industrial building.

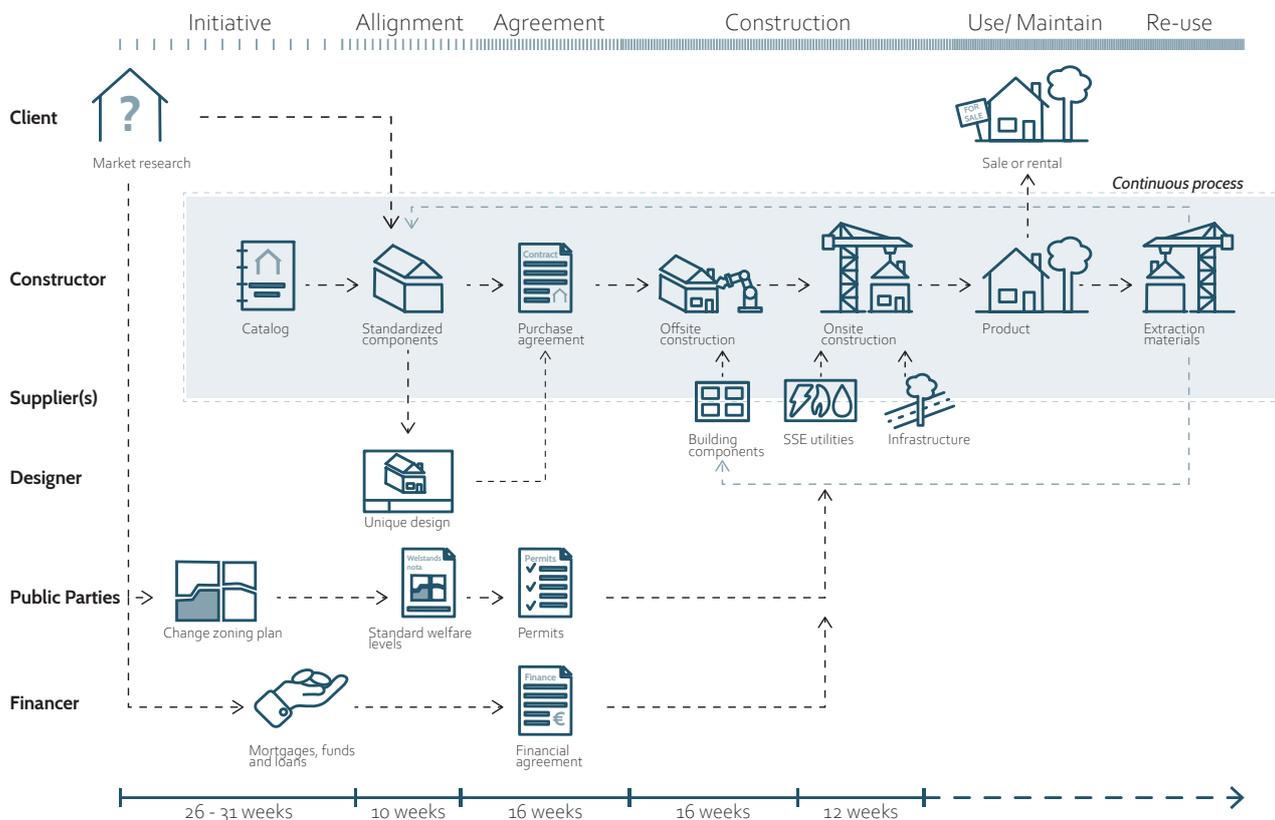


Figure iv - The industrial production process

The opportunities and barriers that were found are combined in appendix IV. This has been done for each part of the study, theoretical and empirical for the product, process, and project.

Conclusions

The conclusions provide recommendations for each part of the empirical research (product, process, and project) and each main actor (constructor, client, and public parties). In addition to each recommendation, a list of conditions is given. The recommendations are based on the findings and further adapted and broadened based on the validation by the expert panel.

- Constructors should take the lead in the innovation and digitalization of the product; the rest of the parties should steer to develop a product that meets their needs.
 - Constructors should get in-house knowledge and experience about producing in a factory.
 - Constructors should keep communicating with the market, listen to customers, and show them what they have to offer.
 - Public parties should steer on environmental innovation and minimum quality requirements.
 - Public parties should help constructors with the facilitation of innovative programmes.
- Public parties should work with a long-term vision, standardization in the processes and national guidance and regulations.
 - The government must give notice of new regulations whereby four-year policy is transcended.
 - The government should make a guiding plan with prioritising guidance.
 - The government should provide structural money to help see the market.

- *Public parties should together standardize the documents that are used in the processes with digitalization (developed by constructors, recommendation 1)*
 - *Municipalities should consider products that are not 100% compliant.*
 - *Municipalities should not exclude industrial products with the welfare levels.*
3. Clients need to take on a new role where they start thinking in terms of the product and about projects from an overarching perspective.
 - *Clients need to understand the industrial product (covered in the 5th recommendation)*
 - *Clients need to have more insight into the available products (covered in the 1st recommendation)*
 - *Clients should consider long-term cooperation with constructors.*
 - *Clients need to get their employees on board with a new challenge in the product.*
 - *Clients should approach the product like real estate, where more than one uniform product is needed.*
 4. A building flow creates cooperation and trust in the product among clients and public parties, and this accelerates innovation with a learning curve for industrialisation.
 - *Between clients and constructors, there should be a possibility to talk about concessions in the product.*
 - *Constructors should be willing to talk about their product and show what their product can do.*
 - *Clients must define requirements for the product that fit each project; this could include multiple types of products in the invitation.*
 - *Clients must stick to the product they have defined after the agreement.*
 5. Transparent exchange of knowledge about industrialised products and processes leads to trust and cooperation between parties, which in turn creates internal motivation for cultural and organisational change.
 - *All employees involved in industrialisation must be included in this change.*
 - *Clients must stop selecting products only based on the lowest price.*
 - *Constructors must learn to become more open in the process towards clients and each other.*
 - *Actors should find a place for the informal conversation; this should be small groups of different actors.*

Further research recommendations

The first recommendation for further research is that the developments in the coming years should be monitored with additional studies. In these studies, the scope of industrial housing will have to be continuously reviewed with the developments on the market. In addition, it will be possible to reflect on multiple and completed building flows in the future. This research can look at the advantages or disadvantages of a building flow and compare the different ways in which a building flow has been applied. Differences can be searched for in which actor is involved in which phase, which agreements are made, the way of tendering, and the project's success.

The second recommendation for further research would be to devote further research to the public system. Firstly, this study should investigate how recommendation from this study can be implemented. Therefore, it must be studied how national guidance and regulations can be given substance and how a long-term vision can be implemented. In addition, a study can be conducted into how standardisation can be implemented. It should be investigated what a standard document and procedure should look like and how it will be supported nationally. Besides further research should look at where further optimisation is possible; this includes objection periods, public participation, and the role of welfare levels.

Alongside recommendations for further research to optimise the process, further research will have to be done into how different actors use or would like to use a digital model, subsequently investigating how these digital models work together in a linear process. In addition, follow-up research can be done on the application of industrial housing; think of the production method and the elements of an industrial house. In addition, it can be studied in which way product can be applied, the target group, the location, and the stacking of products.

Finally, it would be interesting to research what is needed for a cultural change in a conservative sector. Therefore, a study on gaining support with the possible role of modern tools can be performed. With the current technology, we can use virtual reality, 3D-modelling and online platforms to show what industrialisation means for our built environment.

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01.

INTRODUCTION

1. Introduction

1.1 Background information

The Dutch housing market is under tremendous pressure since the financial crisis in 2008. The available construction capacity decreased extremely while construction costs have increased. In 2013 the production was dropped from 79000 to 50000 houses a year (Boelhouwer, 2019). At the same time, the population is growing, and individualising is increasing due to immigration, ageing of the population, and changing housing preferences. Although the population will only increase to 4,4%, the number of households will increase by 7,8% until 2030 (ABF Research, 2018). With problems in the construction sector and growing population, the shortages will only increase further.

The increase in households combined with the low production capacity over the last years put huge pressure on the housing market. It is estimated that the housing demand will increase by 839.000 until 2035 (ABF Research, 2018). A recent action plan published in cooperation with 34 organisations addresses the need to realise 1.000.000 houses in the next ten years (*Actieagenda Wonen*, 2021). To solve this major challenge, the government aims to increase the yearly production to 75.000 houses a year (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2020), which means a higher production in a shorter time than we currently have. However, realising those required new objectives is currently not feasible because the market cannot produce these quantities. Furthermore, even if we succeed in realising 75.000 houses, we are still 25.000 a year short according to the recently published action plan.

With the publication of new reports, the shortages seem only to be increasing. As mentioned, this problem started after the financial crisis in 2008. The construction industry had reached an all-time low. The construction capacity had fallen sharply, which causes the loss of capacity and the loss of knowledge (van der Heijden & Boelhouwer, 2018). It takes time to reinstate this capacity to a required level; this has not been successful yet.

Besides, the sector has to deal with many influences from the government. The Netherlands has an active land policy, municipalities have more control over when which location is developed, but the crisis has ensured that fewer financial risks are taken by the government (Nieland et al., 2019). The uncertainties that come with this also cause uncertainty for the construction industry and developers.

Meanwhile, the housing challenge has become larger and more complex due to the increasing emphasis on sustainability (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2020). The built environment must respond to the global climate crisis, and this means that the government will steer on innovation with subsidies, regulations, and agreements within the sector.

One of the solutions to solve this production capacity problem is the large-scale use of industrial housing. Houses that are industrial offsite constructed in transportable components can be the breakthrough (McKinsey & Company, 2019) reducing order lead time and creating variety with limited resources. In the construction industry, the implementation of modularity has been limited to off-site production (OSP). Multiple building companies developed prefabricated or modular products to answer the housing shortages to create efficient, flexible, and affordable housing on a large scale. Higher and faster production can be reached by moving the construction to a factory and only assemble the houses on-site at the location (Huijbregts, 2020). The benefit of industrial housing includes sustainability and circularity with a more efficient process and reduces the risks.

1.2 Problem statement

Despite these benefits and the proven industrial housing methods and facilities that are available, most of the new houses are still constructed in a traditional way. This means an extensive program, a long process, high risks, and high building costs. In addition, for every project, a new plan is developed. There is a high potential in industrialised products, but constructors are not sure how to leap a way that guarantees reliable advantages (McKinsey & Company, 2019).

The first problem is that there is much confusion about the concept of industrial housing. Many think that we are already industrialising by using prefabricated materials (Van de Groep, 2020). However, prefab has been the standard for at least 50 years, and industrialisation goes far beyond this. The offsite production of separated parts is not the innovation we need for industrial housing. For this transition,

we talk about offsite production on a large scale based on a production chain. To initiate this production chain, the constructor must invest in the construction of a factory. A factory means a high one-time investment that is therefore only reserved for the larger organisations and only becomes profitable with a minimum production. This large investment makes companies hesitant to invest and need to see a potential for a sustainable business development (McKinsey & Company, 2019). This hesitation of these companies is the second and even more significant problem for a successful transition.

Besides constructors that develop a product, multiple other actors are involved in the process, for example, housing cooperation, investors, and public parties. Every actor in the process must act to make the transition; they all must change their way of working and need to cooperate. Multiple constructors developed a product, but they face the issue that the production process is not ready for upscaling. To scale up a structural cooperation is needed, but different barriers hinder this transition towards the optimal use of the production process. This is the third problem.

1.3 Research goals & objectives

This research analyses the topic of industrial housing and the opportunities and barriers to scale up the production with adaptations in the process. To provide insights to actors in the market of industrial housing and improve the production process of industrial housing, the goal of this research is **to identify the adaptations in the process that are needed to scale up the production**. Thus, the main objective is to determine the current opportunities and barriers that are unused or need to be overcome. Derived from this analysis, the goal is to provide a systematic overview of adaptations needed to use the opportunities and overcome the barriers. The more specific objectives of this research are:

1. *To gain an understanding of the meaning of industrial housing.*
2. *To gain an understanding of the traditional and industrial production process of houses.*
3. *To identify the characteristics that might influence the industrial process compared to the traditional process and other industries.*
4. *To identify barriers and opportunities that are experienced in the production process of different industrial housing products.*
5. *To determine how different production processes can learn from each other in order to optimise.*
6. *To define how the production process of different industrial housing products can be optimised.*

1.4 Dissemination & audiences

The outcome of this research gives insight into the transition of industrial housing from a scientific perspective. Several studies have been conducted in the field of industrial housing, both in the field of academics and in practice. This research aims to bring the academic field and practice together with a theoretical framework from the academic field and its application to practice.

By bringing these fields together, this research is an interesting document for both fields. The academic field can learn from the relation between theory and practice on the Dutch housing market. Besides, it provides information and an overview of industrial housing that is currently not there.

For practice, this research is relevant because it addresses the current problems concerning housing shortages. It explains how industrial housing can answer this shortage. Besides, it helps to optimise the process of industrial housing. In this research, recommendations are given to help overcome barriers in the process of industrial housing. With these recommendations, the problems, mentioned in the problem statement, can be overcome. For the parties involved in the production process, this research can provide a basis to evaluate their current position and gives recommendations that could be implemented to improve their process.

1.5 Data plan

The data for this study is collected through document reviews, interviews, and knowledge from practice. Parts of the data is based on people's experience and opinions in the field or within an organisation. This data needs to be handled carefully and confidentially. Besides, this research aims to make data available for knowledge discovery, innovation, and reuse for further research. Therefore, the data of this research

is treated according to the FAIR Guiding Principles to make it Findable, Accessible, Interoperable and Reusable (Wilkinson et al., 2016).

- The final thesis will be published on the educational repository of the Technical University of Delft (Tu Delft), through the following link: <https://repository.tudelft.nl>
- Data that is not directed attached to this document can be requested by sending an email to the author via the following mail address: tessameij@gmail.com
- This research is written in formal, accessible and broadly applicable language. Dutch terms will be mentioned ones with the Dutch terms in brackets. Both terms and interview data will be translated into English as truthfully as possible.
- Interview transcripts and other obtained data will be structured and richly described with detailed provenance.

Sensitive data that is part of this research will not be shared. Data that is currently not attached will only be provided with the permission of the person involved. Meaning that when data is shared, it is ensured that sensitive data is blurred or left out, and no data can be traced to a specific person.

1.6 Research questions

The problem definition has led to the following main research question:

What adaptations are needed to scale up the Dutch production of industrial housing?

Sub-questions have been formulated to answer the main question:

- Q1 - What is industrial housing?
- Q2 - What are the benefits of industrial housing?
- Q3 - How are different actors currently involved in the process?
- Q4 - How does the current production process of traditional and industrial housing work?
- Q5 - What are the opportunities and barriers for industrial housing?
- Q6 - How can the opportunities be optimised, and the barriers overcome?

02.

RESEARCH METHOD

2. Research method

2.1 Research Design

Figure 2.1 shows the structure of this design in a research framework. The process is divided into three parts, 'theoretical', 'empirical' and 'synthesis'. The sub-question that is answered in a section is placed in the second row. Underneath the method, the output that relates to a phase can be found. The visualisation of the research method helps to understand this research's structure and see if any steps are missing. It gives a visualisation of the connections in the process and way of information gathering.

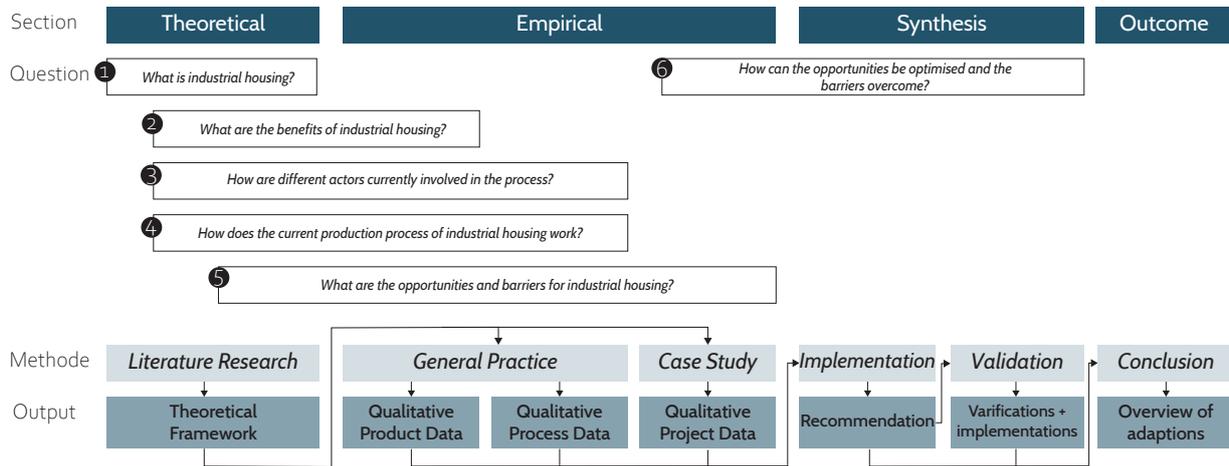


Figure 2.1 - Research method (own illustration)

2.2 Methods and techniques

Figure 2.2 shows the used methods and techniques to conduct this research. Each method relates to one or two techniques. The main techniques for this research are reviews, interviews, and analysis.

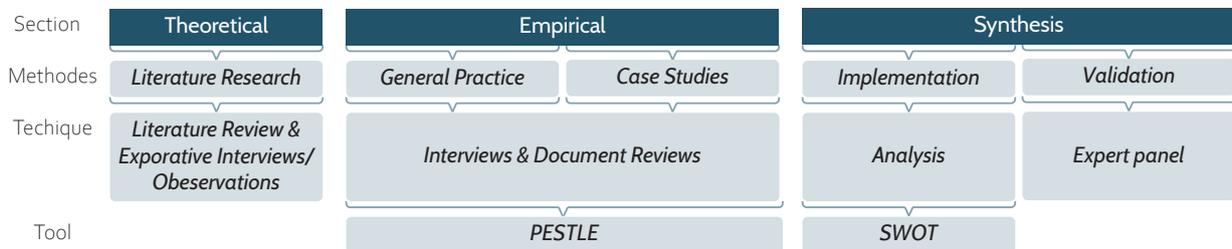


Figure 2.2 - Methods and Techniques (own illustration)

To structure the data, PESTLE is used as a marketing tool and SWOT as an analysis technique. However, the PESTLE tool has been adapted since not all elements are applied, and other elements were not covered specific enough. Therefore, only the relevant elements of this framework are used in the theoretical review, explorative interviews, or observations in the field. These are:

- **(P) Political:** The role of the government and the impact government policies concerning industrial housing.
- **(Ec) Economic:** Factors that impact the economy, which directly impacts the production process. This includes the costs for companies to be part of this production process.
- **(S) Social:** The impact of the social environment on industrial housing. This includes a growing population, individuality, and ageing, but also the change in the type of housing and housing trends.
- **(T) Technological:** Innovation that could affect the market and thus the production process of industrial housing.
- **(I) Institutional:** The influence and power of institutions and their cultural and organisational habits.
- **(Ev) Environmental:** The influence on the surrounding environment and impact on ecological aspects includes the current climate change concerns.

2.3 Theoretical review

The first phase is focused on the literature to get familiar with the subject of industrial housing. This is done with a literature review, explorative interviews, and observations in the field. The observation of the practice is carried out in its broadest sense. The subject is much discussed in practice, such as webinars, meetings, and factory tours. These are all opportunities to get a better understanding of the field.

The literature review will first elaborate on the concept of industrial housing to clarify the scope of this research. The confusion about industrial housing and its boundaries will be clarified. After that, it is essential to get a better understanding of the current state of industrial housing. The transition started a long time ago, which means there are already multiple steps made, but this does not mean that they are still relevant. To investigate which steps are needed now, it is crucial to understand what is already done and its effect. This means that lessons learned in the past should be considered and translated to their future use. It will then discuss the benefits of industrial housing so that it is possible to reflect throughout the research whether the goal is still being achieved. Finally, an overview of the actors is provided. There are many actors involved in the process who are the key to changes in the process.

The theoretical review concludes with an overview, the theoretical framework. This theoretical framework gives substance to the tool PESTLE used in the empirical research and synthesis. After the theoretical research has been carried out, a better understanding of using these tools in the industrial housing process is obtained. The tool should capture the characteristics within the benefits and current position of industrial housing. Besides, the theoretical overview gives a framework to compare the process of different housing products. This framework consists of the traditional and industrial process with the actors that are involved.

2.4 Empirical research

The empirical research is the second phase of this research and is divided into two parts of qualitative research, 'general practice' and 'case studies'. In qualitative research, an exploration of the subject is undertaken to gain a better understanding of the subject (Glaster & Strauss, 1967). Besides, qualitative research tends to determine why things happen as they do (Fellows & Liu, 2015). Both are needed to answer the main research question.

General Practice

This section is an analysis of the barriers and opportunities experienced by the actors involved in the process. The actors involved in the process are constructors of the different products, housing corporations, developers, suppliers, public parties, and residents. The theoretical framework gives insights into the current situation of industrial housing; there can be lessons learned from this context that led to opportunities or barriers. However, this is unlikely to be fully substantiated in practice. Besides, it is assumed in advance that this does not provide all the information. Industrial housing develops fast, which means that written theory is most likely to be one step behind. Therefore, interviews have been conducted with actors in the process.

In the first phase of this study, some exploratory interviews were conducted. These interviews can be interpreted as conversations about industrial housing and the process to understand the field better. After this phase, in-depth interviews were held. These interviews initially focus on two things, the product and the process. On beforehand, it was assumed that this part would deliver a comparison of the different products. The different products could be seen as different cases and would be the case study part of this research. However, during the interviews, it became clear that this was less relevant for this research's direction. The focus on the process is more important than the product; this will be explained in chapter Part 1 – Product. Therefore, it was decided to use an example project as a case study. This project has succeeded in improving cooperation between actors to promote a fluent process. During the interviews, a focus on the project was therefore added to the product and the process. Additional to the in-depth interviews, broadening interviews were held. These broadening interviews gave more specific insight into the subject of the process.

Selection of interviewees

As mentioned earlier, the empirical research contains interviews with different actors involved in the process. Essential for the selection of interviewees is to understand that an actor can have different

roles. It is possible to have two or more interviewees from one actor with a different role.

The interviewees for the exploratory and broadening interviews were selected on their knowledge about a specific subject. These interviewees were selected within the organisation of Heijmans because these persons were easy to contact and open to contribute. The information gained in these interviews is not organisation specific, and the data is not directly used as input for the results.

For the in-depth interviews, the first selection was made from different constructors of industrial housing product. From each organisation, an interviewee with knowledge about the future of the product was asked to contribute. The selection's main criteria for this interviewee are that the constructor's product falls within the scope of industrial housing, as defined in chapter 3.2. Besides, the organisation must have incentives to scale up the production of a product or have a product that already has a large market. These criteria are translated to criteria in the number of realised or planned to be realised houses. A concrete plan means that the client has approved the plan and the location for the project. Finally, it is possible to realise the product as a ground-based house (Dutch: grondgebonden woning). Leading to the following stated criteria:

- The product falls within the scope of industrial housing.
- The product that is built >100 or there are concrete plans to build >100 houses.
- The product is realised as a ground-based house.

As there are several constructors within these criteria, a balance between different types of products produced by the constructors has been sought. The building materials and types of original building type (temporary or permanent) were considered. Different building materials lead to a different process, for example, regarding the reuse phase at the end of the product's lifetime. The original building type can be divided into temporary and permanent; herein are many internal differences in the company's organisational structure. This balance is chosen to have a wide variation in the interviewees. The criteria and the balance formed the first selection of constructors that have developed a product. Within the organisation, an interviewee with knowledge about the product is contacted.

Besides constructors that developed a product, other actors in the process were asked to contribute. Those actors have been chosen once the theoretical part had answered the sixth sub-question: 'How are different actors currently involved in the process?'. The theoretical framework, therefore, formed the input for the second selection of interviews. Besides, the selection was based on the following criteria:

- Actors that are involved in a context that is similar or comparable to the context of today.

During the research phase, the list of interviewees developed by interviewees suggesting persons with new perspectives. This method is also known as the snowball sampling methodology. This methodology uses the social networks of interviewees to expand the researcher's potential contacts and play a key role in locating, accessing and involving hidden and hard to reach potential interviewees (Cohen & Arieli, 2011).

Case Study

During the explorative interviews and observations of the field, it became clear that adaptations in the process, as opposed to the product, have more impact on the realisation of higher production. For the case study, it was decided to focus on an example project instead of different housing products. This section is a case study analysis of the barriers and opportunities experienced in the process of a specific project. The case study is used to broaden the data collection. Cases that are theoretical relevant will help generate as many properties of the categories as possible. (Glaster & Strauss, 1967).

In this case project, the actors are striving for better cooperation between the different parties. This case should not be a starting point for the optimisation of industrialisation. However, in general practice, the focus is mainly on the product to improve the process. In other words, first, there is a product, and then the process needs adjustments. Whereas in this case, the process and its corporation are taken as a starting point. There can be lessons learned from this different view on optimisation.

Selection of the case

In this research, the case is chosen as an example that contributes with data from another perspective. It can be discussed that a single case does not deliver a complete picture of reality. The issue of single

case studies is, among others, discussed by Flyvbjerg (2006); he argues that a single case can be used to learn something rather than prove things. In this research, the case is used among other methods aiming to learn something from this process and cooperation. This learning also occurs in single cases, whereas 'the force of example' is underestimated (Flyvbjerg, 2006). Because a single case is used, validity can be added to the findings by using multiple sources of evidence per case (Yazan, 2015); this is done by interviewing three different actors involved in the case project.

The case that is selected for this research is the urban area of Eindhoven. This case is selected based on information gained during the explorative and first in-depth interviews. To innovate industrialisation, multiple actors decided to work together in a building flow (dutch: Bouwstroom). This building flow is an initiative that stimulates corporations and actors in the construction chain to work differently (Aedes, 2020). Collective commissioning ensures a continuous and predictable market, allowing industry and constructors to produce optimally. In the Netherlands, multiple regions have made the first steps for a building flow. However, at this moment, no houses have been built in a building flow yet. One of the frontrunners is Eindhoven's urban area. They are the first building flow where the municipality, corporations and constructor are involved and where an agreement has been reached between the corporations and constructor. This first step towards success delivers data about opportunities and barriers for a construction flow.

Data collection

The techniques used for this data collection are document reviews and interviews. The document review has been done with publicly available documentation or retrieved from organisations, product developers, or other involved organisations. Interviews are used to obtain data about the practice. On beforehand, some information on the research was given (see appendix II). The interviews are also semi-structured because the purpose of these interviews is to learn from practice; the interviews were conducted using a protocol (see appendix III). The flexibility leaves space in the interview to have an interesting conversation about the lessons learned. They tend to be flexible and responsive in how the interviewees take the interview; this leaves space for issues that surface during the interview (Bryman, 2012). This space for surfacing issues is important because the interviews add information that did not show up in the document review. However, it is unclear beforehand what the missing information is.

For the analysis of the product, the scope, and benefits of the product from the theoretical framework are used. The theoretical framework clarifies what industrial housing means for actors in the field. Besides, this framework is the underlayer to find barriers and opportunities to innovate the product. Interviewees who have developed a product are questioned about their experience with their own product, while other actors are questioned about their general experience with different products.

The second part of the interviews is focused on the process and how different actors act in this process. The process illustration from the theoretical framework is used to get interviewees on the same page. During the interviews, this scheme was further elaborated based on information provided by the interviews. For the interview structure, the complete framework with identified opportunities and barriers was used in appendix I. This framework gives direction to the different perspectives and helps when interviewees do not know how to answer. This framework is based on the PESTLE tool; this is useful for a complete data collection and makes the data comparable to the theory and the case study. PESTLE has the purpose of talking about the concept from every external point of view. For the case study interviews, the same protocol as for the in-depth interviews is used. However, these interviews are more focused on the case, and additional case-specific questions were asked.

A total of 21 interviews (*Table 2.1*) was conducted within 15 different organisations. From the total number of interviews, 13 work as product developer from 8 different organisations, 7 construction companies and 1 developer. The other interviews were performed among 3 public parties (municipalities and province), 2 other clients (area developer and housing corporations) and 2 external actors (consultancy firm and association of housing corporations). With 16 persons, the interview was about was an in-depth interview, of which 3 were case-specific. The in-depth interviews are transcribed for the data collection, while the exploratory and broadening interviews were only summarised.

	x#	Organisation	Date	Way	Subject
Exploratory	A1	Heijmans	15-2-2021	Face-to-Face	Decisions for a new product
	A2	Heijmans	15-2-2021	Face-to-Face	Commercial real estate perspective
	A3	Heijmans	18-2-2021	Video call	The current building process
In-depth	B1	Heijmans	16-2-2021	Video call	General practise
	B2	Heijmans	23-2-2021	Video call	General practise
	B3	Aedes	26-2-2021	Video call	General practise
	B4	Finch Buildings	8-3-2021	Video call	General practise
	B5	BRINK	10-3-2021	Video call	CaseStudy
	B6	Provincie ZH	10-3-2021	Face-to-face	General practise
	B7	Havensteder	11-3-2021	Face-to-face	General practise
	B8	Koopmans - TBI	15-3-2021	Video call	General practise
	B9	BPD	16-3-2021	Face-to-face	General practise
	B10	Gemeente Delft	17-3-2021	Video call	General practise
	B11	Jan Snel	19-3-2021	Face-to-face	General practise
	B12	Volker Wessels	23-3-2021	Video call	General practise
	B13	Van Wijnen	24-3-2021	Video call	General practise
	B14	Gemeente Helmond	25-3-2021	Video call	CaseStudy
	B15	Heijmans	26-3-2021	Face-to-face	CaseStudy
Broadening	C1	Heijmans	4-3-2021	Video call	Digitalisation
	C2	Heijmans	9-3-2021	Face-to-face	Building site visit
	C3	Heijmans	3-5-2021	Video call	Traditonal process

Table 2.1- Overview of selected interviewees (own table).

2.5 Synthesis

In the synthesis, the results of the research are analysed, validated, and implemented. Yin (in Yazan, 2015) describes this as the logical sequence that connects the empirical data to a studies research question. The result of this chapter are the recommendations with the expert panel’s comments, which lead to the final conclusions.

Implementation

All findings from the empirical research (the general practice and case study) are compared to the theoretical framework. The analysis is made by using PESTLE with opportunities and barriers for each element is the basis for this synthesis. First, SWOT will define the different layers of this analysis, and triangulation will make the case, general practice, and the theory comparable. Triangulation entails using more than one method or source of data in a study (Bryman, 2012); data is contrasted and compared with each other. In this way, triangulation can also be a qualitative research strategy to test validity

through the convergence of information from different sources (Carter et al., 2014). The triangulation of findings has led to different recommendations (see Figure 2.3). When findings contradicted each other, and a logical recommendation was not found, a recommendation to provoke confirmation or refutation was created and presented for validation by the expert panel (see Figure 2.4). This synthesis leads to a first answer to the main research question with recommendations for the practice and further research.

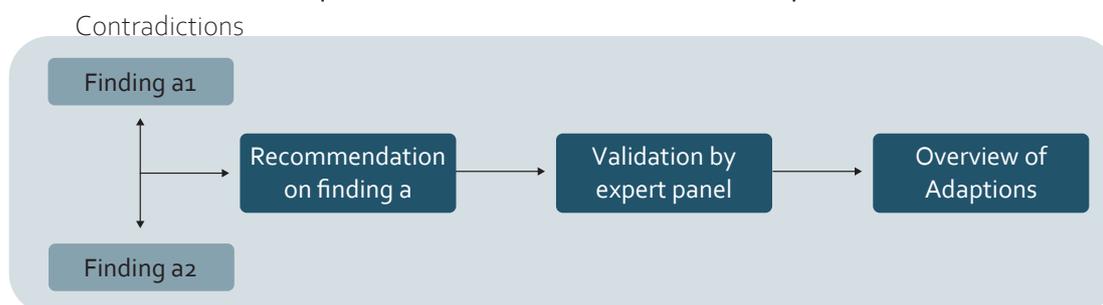


Figure 2.3 - Triangulation findings (own illustration)

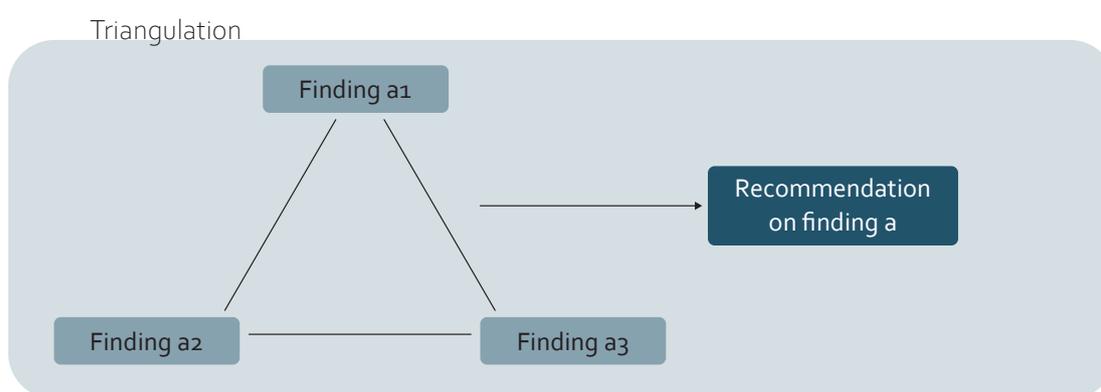


Figure 2.4 - Contradictory findings

Validation

To validate these recommendations, an expert panel will reflect upon the recommendations. An expert panel is an effective method for complex issues that require synthesis from many different disciplines (Slocum, 2003). The expert panel is used to verify these recommendations and avoid any final contradictions. Professionals with different expertise and positions in the market were asked to contribute. During the expert panel, the recommendations were presented in the form of a proposition. Professionals were first asked to vote against or in favour of the proposition where after an open discussion was started. New insights gained during this panel will be included in the conclusion.

In Table 2.2, the professionals that participated in the panel are shown. The expert panel information sheet and additional information can be found in Appendix V and VI. The expert panel was held in Dutch, as was the documentation they received beforehand.

	x#	Organisation	Date	Way	Perspective
Expert panel	D1	Heijmans	10-5-2021	Video call	Constructor: The housing market
	D2	Heijmans	10-5-2021	Video call	Constructor: Marketing of the product
	D3	Heijmans	10-5-2021	Video call	Constructor: Development of the product
	D4	Aedes	10-5-2021	Video call	Association of housing corporations
	D5	Provincie ZH	10-5-2021	Video call	Public parties

Table 2.2 - Overview of expert panel participants (own table)

03.

THEORETICAL
REVIEW

3. Theoretical review

3.1 Historical background

Standardisation and the use of modular construction have been around for years. These developments started in the Industrial Revolution when there was a real drive to combine standardisation with a systematic building. In this revolution, the industry had to respond to an urgent need to benefit that the offsite fabrication and factory-based building component industry was growing (Gibb, 2001). This innovation was the start of industrialisation, but still, the realisation appeared limited. During the first world war, there was a disastrous effect on the housing market, with a demand for a fast and economic rebuilding of the housing stock. There was an acceleration in the industrialisation of housing (Ågren & Wing, 2014). This acceleration was repeated during the second world war, but this time also affected the Netherlands.

Due to the housing shortages, there was a great deal of attention for prefabricated building components after the second world war. It was the alternative to combat the significant shortages of (affordable) housing and was therefore stimulated by the government. With a system of subsidies and certainty on the construction market, the prefabricated construction industry reached its peak in the mid-1970s, with around 35000 houses a year (Huijbregts, 2020). This peak was called a mass production of the same houses that used prefabricated building components. After this peak, there was a movement within the society; quality became more important than quantity. Constructors of prefabricated building components had to compete against small traditional constructors (de Vreeze, 1993). The resistance against mass production came mainly from architects. There was too much uniformity and not enough flexibility and resident's participation, which eventually brought industrialisation to a standstill around the mid-1980s (Huijbregts, 2020).

It became clear that the building industry is an industry that is hardly accessible for renewal. This has to do with structural elements of the building industry and its complicated relationships between actors. The characteristics that slow down innovation in the building industry are

- Design and construction are more separated than in other production sectors.
- The production of one house is an ad hoc cooperation between multiple different actors.
- The market is not well suited for structures produced in series or obtained from stock because the demand is often specific for a determined location.
- The sales opportunities are influenced by other factors than price and quality, such as location-specific requirements, spatial planning, welfare requirements and financing.
- There is a non-transparent and challenging to predict competition from other developers and the existing built environment (de Vreeze, 1993)

These requirements have caused a failure of industrialisation in this period and cause the attempts to produce a complete industrialised house to fail. Nevertheless, the influence of industrialisation was still visible in traditional housing. Not all houses were produced the same way, but prefabricated components such as concrete floors, roof slabs, skylights, balcony fences, and appliances were used (de Vreeze, 1993).

At the end of the 1990s, the building industry started to innovate again. The innovation through time can be described with the spatial degree, and the degree of intelligence visualised in Figure 3.1. The step from traditional to system construction can be explained with four developments:

1. An intelligent system for design and production
2. Modular build product
3. Sustainable chain cooperation
4. New transaction process (Huijbregts, 2020)

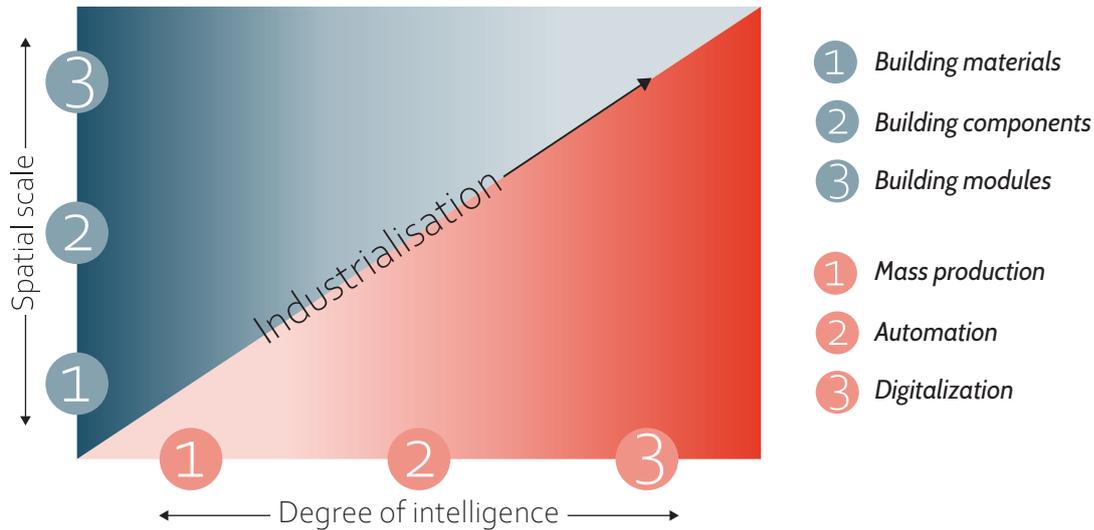


Figure 3.1 - Innovation trough time (based on Huijbregts, 2020)

In this period, the industrialisation of constructions obtained new name labels than before (Lessing et al., 2015). The industry developed different technologies of production described by Gibb and Pendlebury (2006) in four phases. In the Netherlands, the development in chronological order was labelled as system construction (*Dutch: systeembouw*) with mass customisation (*Dutch: massawoningbouw*), conceptual housing (*Dutch: conceptueel bouwen*) and modular building (*Dutch: modulair bouwen*), whereafter the industrial housing phase follows (Huijbregts, 2020). Figure 3.2 illustrates the development from traditional via system construction to industrial with the spatial scale and the degree of intelligence.

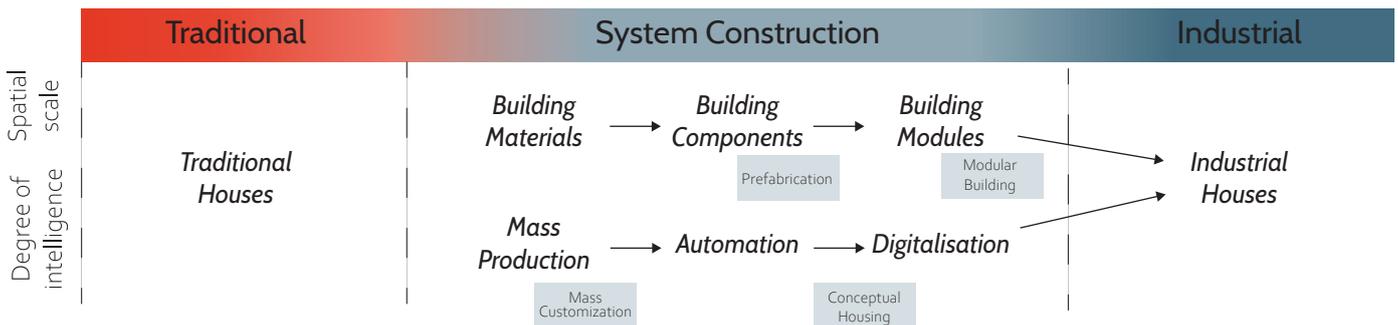


Figure 3.2 - Development Industrialisation (own illustration)

3.2 Scope definition

The approach of standardisation and preassembly is not new and, in most ways, not innovative (Gibb, 2001). This development through the years has led to different ways of labelling for different techniques. However, a clear definition of the different labels is missing, which also become apparent in the historical background. Therefore, this chapter gives a definition of industrial housing used for this research and the position of industrial housing compared to industrial development through the years.

Lessing was one of the first that attempted to clarify that industrial housing integrates several constructions with standardisation and prefabrication (Lessing, 2015). The concluded definition given in

his research was: “Industrialised house-building is a thoroughly developed building process with a well-suited organisation for efficient management, preparation and control of the included activities, flows, resources and results for which highly developed components are used in order to create maximum customer value.” (Lessing, 2006)

The industrialisation of housing is a change in the building process towards a more mechanical and automated production. This process includes prefabricated parts or modular components and the use of digitalisation with robotisation.

The step from system construction to industrial is a combination of spatial scale developments and the degree of intelligence. The spatial scale explains the scale of building products that are produced onsite and offsite. Traditionally half products were brought to the construction site, but the industrialisation had led to the combination of elements offsite. The degree of intelligence indicates the level of automation, digitalisation, and data exchange.

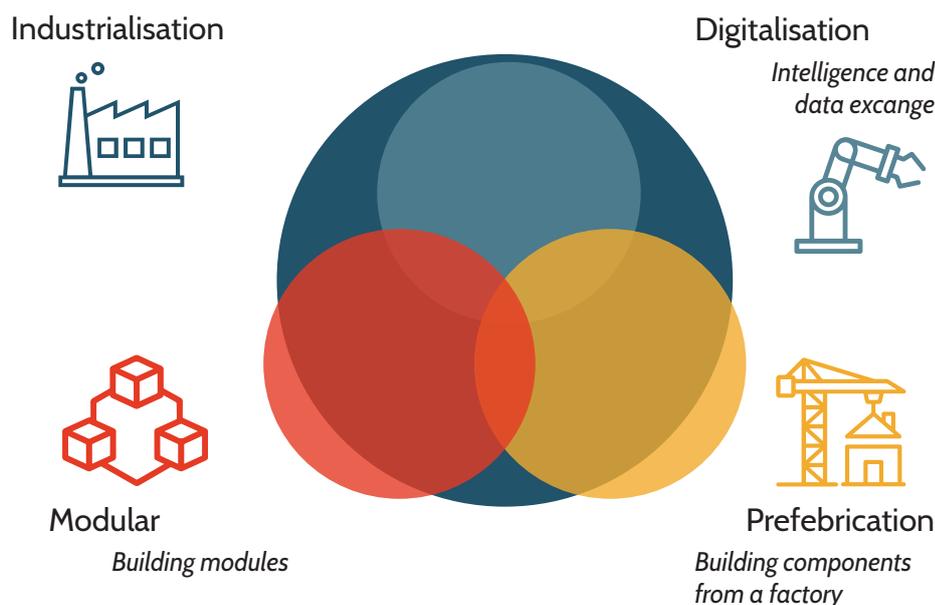


Figure 3.3 - Connection labels of development

The connection between the different labels of development and overlap in industrialisation is illustrated in Figure 3.3. The result of combining these developments lead to an industrial house. This industrial house is manufactured using a digitised offsite fabrication method to produce standardised houses. The result of this fabrication is not a concept but a final product.

3.3 Benefits of industrial housing

Industrial housing could answer the housing market shortages, but there are more reasons why industrial housing should be the answer to housing in the Netherlands. The benefits are divided into three groups, product, process, and environmental benefits. The product and process benefits include answers to the housing shortages and are beneficial for the final product. The environmental benefits are additional advantages that impact our living environment.

Product benefits

The optimisation of industrialisation is a process that leads to a continuous **improvement of the quality** of the product. This quality improvement includes better **control of quality** from factory-made products than could be achieved on-site, **consistency of quality** and the fact that a factory’s construction is more likely to be engineered to fit correctly (Gibb & Isack, 2003). This quality control and consistency lead to **less construction mistakes** than in a traditional onsite produced product. The factory where products are produced works with optimal working conditions; this means, for example, the perfect circumstance for curing concrete (ING Economisch Bureau, 2020). Finally, the process’s benefits that optimise the process leads to a **cost reduction** of the product. Meaning that the price of houses will be lower, which is beneficial for the developer and the housing market.

Process benefits

The main benefit of the industrial building process is the **reduced construction time**. A reduced time means that housing shortages will be solved faster. However, a reduced time is also in favour of the constructor. It means that they have more certainty about meeting the completion date, they can benefit from an early income due to shorter projects and have less risk in changes on the market (Gibb & Isack, 2003). The industrial houses are offsite constructed in a factory. Because most of the construction is done offsite, it is **not affected by external factors**, such as weather or onsite preparation work onsite (ING Economisch Bureau, 2020). These external factors can onsite lead to delays. Besides, the production process is **continuously optimised**, leading to a **reduced process time** and a **reduction of issues** in the construction (Aedes, 2020). For the constructor, optimising the process and reducing mistakes means **less risk** in developing a new project. A new project with industrial houses has the same process as previous projects and builds further with knowledge and lessons learned.

Environmental benefits

Besides benefits in the product and the process, industrialisation also has a positive effect on our environment. The development of this new product uses the possibility to answer global climate change. The new developed industrial houses in the Netherlands meet an energy-neutral house's requirements (*Dutch: Nul-op-de-meter woning*) for an affordable price. These houses are therefore **more sustainable** than other houses in this price range. Besides, industrialisation makes it possible to **reduce waste** due to the new construction methods and technologies available for the housing industry (Tam et al., 2007). Most new industrial houses are delivered with a **material passport**. This passport makes it possible to determine which materials are present in a building at the end of its lifetime. Therefore, it makes it possible to reuse materials or even make the process **circular**.

3.4 Actors

This paragraph explains the role of the actors that are involved in the construction process. In the problem statement, it is explained that better cooperation between actors is needed.

The client

The client is the initiator of the project. Most clients have been professionals in the construction field; they have built up their expertise. Clients can roughly be divided into the following categories:

- Owner of the land
- The future owner of the building
- Project developer
- Executing contractor
- Financier
- Government
- Housing corporation (Wamelink et al., 2010)

A client may be classified into several categories. For example, a project developer can also be the owner of the ground and the building to be constructed. For industrial housing, the client is influential in the decision to use an industrial housing product. Clients have a different opinion about the use of industrial products and ultimately those who take the initiative to use an industrial product. Besides, they had a variety of experience which can be both positive or negative. (Gibb & Isack, 2003)

The constructor

The involvement of a constructor varies from project to project. This has to do with the phases constructor is involved in the project (early or later in the process) the role he takes (advising, collaborative or only executive) and the contract form he agrees on (Wamelink et al., 2010). The traditional construction process can be divided into designing and constructing, with the constructor responsible for the construction. In the industrial process, the constructor is still responsible for the construction but is already involved in an early phase to deliver specification and construction requirements to the architect. These constraints make it possible to construct within the possibilities for a specific industrial product.

Suppliers

Suppliers are actors with an agreement with the constructor and are not directly in contact with the client. The supplier provides a service or a product to the constructor, for example, brickwork, window frames, roofs, and installations. In this research, actors that deliver a service or product to the surroundings of the house are also seen as suppliers. These parties help create the environment, for example, water, gas and electricity supply, infrastructure, and landscaping. Suppliers are used because they often have more in-house knowledge and skills in their expertise. They provide a product or service that the constructor does not have. Many large constructors tend to have multiple subcontracts with suppliers to have more flexibility in their organisation (Wamelink et al., 2010).

Designer

This actor is traditionally known as the architect, but this role has changed due to industrialisation. For this research, to indicate that this actor has a different role, the actor is labelled as a designer.

Traditionally the architect is an all-around builder who advises the client from the first initiative phase; he translates the client's wishes into a design. In the last decennia, the architect's role changed from a delegated builder to a team member responsible for the design. (Wamelink et al., 2010).

This transition is also visible in housing projects. In the traditional process, the architect designs the building consults with the constructor and comes with an adjusted design. This process is repeated until the construction and design are according to the clients' wishes and possible to realise. In the industrial process, the constructor is limited by the possibilities of its product. The designer, therefore, must design within the restrictions given by the constructor. The designer is thus mainly responsible for the appearance of the buildings but must work with the restrictions of the constructor.

Public parties

The public parties can be divided into different scales, from national to local and municipal interest. Within those different scales, they also have different interest, from more houses to a greener environment. Their main task to look after the general interest, but it can be divided into different roles and activities. Creating the right conditions can stimulate the market, such as services, advice, subsidies, and granting permits. Besides, the government must set conditions on a policy level; this is done in the spatial plan (Dutch: ruimtelijke plan), the zoning plan (Dutch: bestemmingsplan) and standard welfare levels (Dutch: welstandsnota). The law makes it possible to regulate the built environment by supervising the programmes and plans against the building decree (Dutch: bouwbesluit).

Financiers

Financiers are involved in the project by the client; these can be banks, life insurance companies and pension funds. With their position, they can impose requirements on the project. (Wamelink et al., 2010)

3.5 Construction process

The transition from a traditional to an industrialised process has led to multiple adaptations in the construction process. This chapter will elaborate on the construction process on two different levels, the organisation of land in the Netherlands and the development of a plot of land. First, it is essential to understand how the housing market in the Netherlands is organised. This gives a better understanding of the role of public parties and the complete process. The development of a plot will be explained by comparing the traditional process to the industrial process. Subsequently, the different phases of the industrialisation process will be examined.

Organisation housing market

In the Netherlands, the zoning plan regulates where land may be used for. Land that is zoned for nature yields less than land for housing because of the value that the land can deliver when it is developed. This means that when land becomes available for housing, the owner is going to make a profit. Besides profit, the possession of land influences what will happen to the land.

In the Netherlands, most ground that comes available is initially owned by the farming industry. As soon

as it becomes clear that land may become available for construction, parties will try to get their hands on those parts of the land. By owning the land, the owner can make a profit when he develops the land and at the same time influencing the plans. Besides, by owning the land, developers are trying to ensure that they are ultimately allowed to build the houses instead of other developers.

When the land is owned by a party that wants to develop, they start the procedures to change the spatial plan. This process takes 2 to 6 months but can take up to 2 to 3 years when an objection is made. When the spatial plan is changed, and they are allowed to build houses, the ground will be made ready for the construction process. This preparation for construction can take months to years, depending entirely on setbacks and delays. These setbacks and delays are caused by unforeseen circumstances such as financial problems, changes in the process, erroneous information, or poor communication. The figure below (Figure 3.4) gives a schematic overview of the described process. There are other routes possible, but this is the most common route. (Centraal Planbureau, 2019)

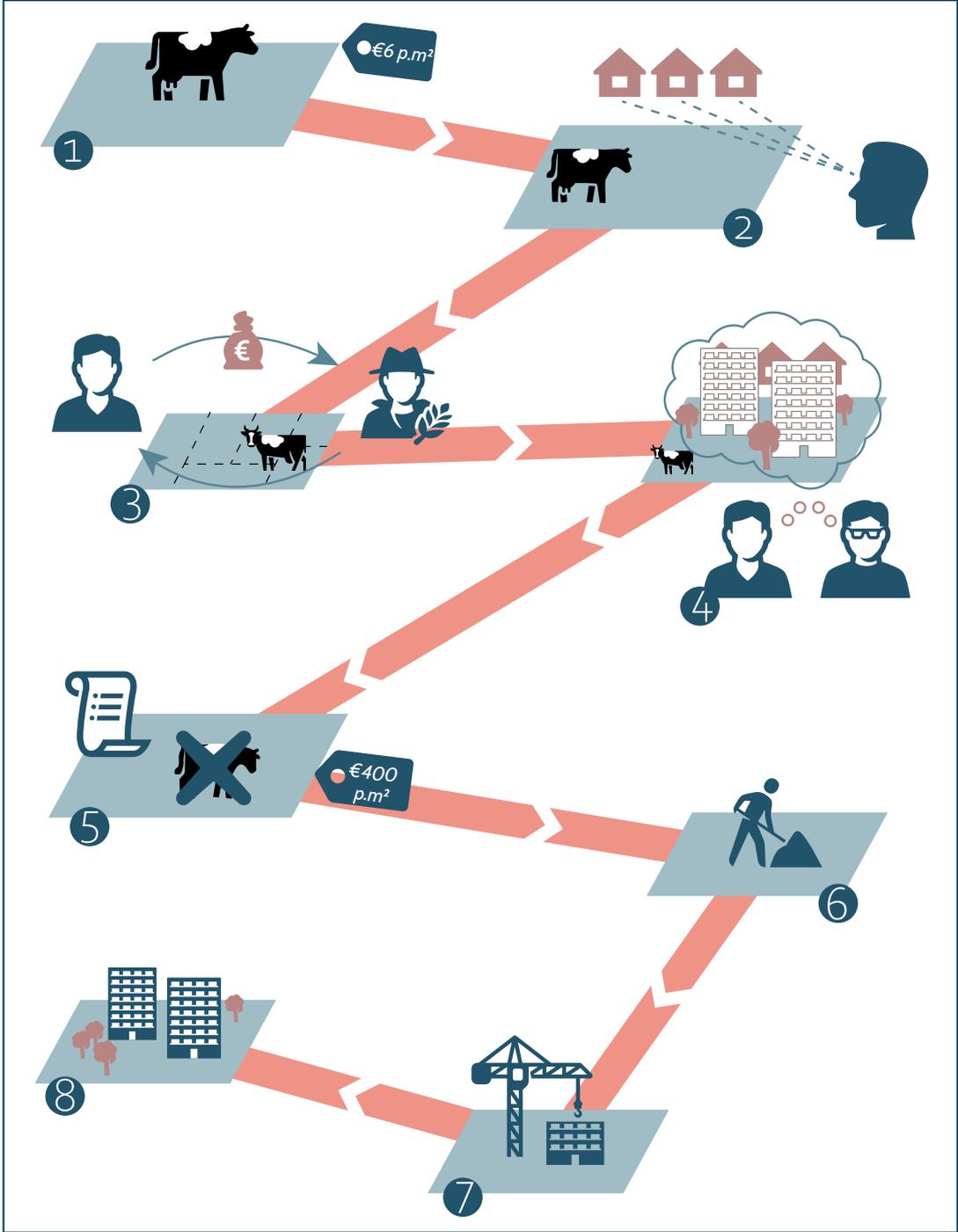


Figure 3.4 - From land to houses (Based on CPB, 2019)

The traditional process

This paragraph will explain the traditional process to understand how this differs from the industrial process. When an actor owns land that he wants to develop, the owner becomes the client for the project. At the beginning of the process, the client hires an architect. It is possible that he also hires already a constructor for an advice agreement. The constructor and the architect will align their ideas about the project with the client's wishes. When an alignment is researched, the constructor starts working on the design in consultation with the architect; this leads to the schematic design, followed by the preliminary design. In the meantime, the client and the constructor consult with the public parties to request the necessary permits. Between the preliminary design and the final design, multiple studies need to be carried out. These are studies on the influence of the construction on the environment and climate, for example, emissions, noise pollution and protected animal species. In addition, research is being done into factors that must be known before construction starts, such as soil investigation. Besides, there is a moment of consultation with the suppliers to integrate their work with the final design. The final design is currently in most housing projects completely designed in BIM (building information modelling) after everyone agreed on it; this takes around 12 weeks. When the project agreement is signed, and all permits are in order, the constructor can start the work preparation. This preparation means that he can start buying building elements and materials from suppliers; because the agreement is signed, he can start making costs. Finally, construction can start on the worksite. (Based on information of Interviewee A3)

The Industrial process

The industrial building process requires a different construction process than the traditional process; Figure 3.5 illustrates this industrial process. The first difference between the traditional process and the industrial process is at the start of a project. In a traditional process, the architect makes a design for the project, after which he aligns this design with the constructor to see if it is constructively possible. For an industrial house, the constructor must be contacted in an early phase of the project. Early involvement of the constructor ensures that the design is also possible as an industrial product—the designer designs with the restrictions that the constructor gives.

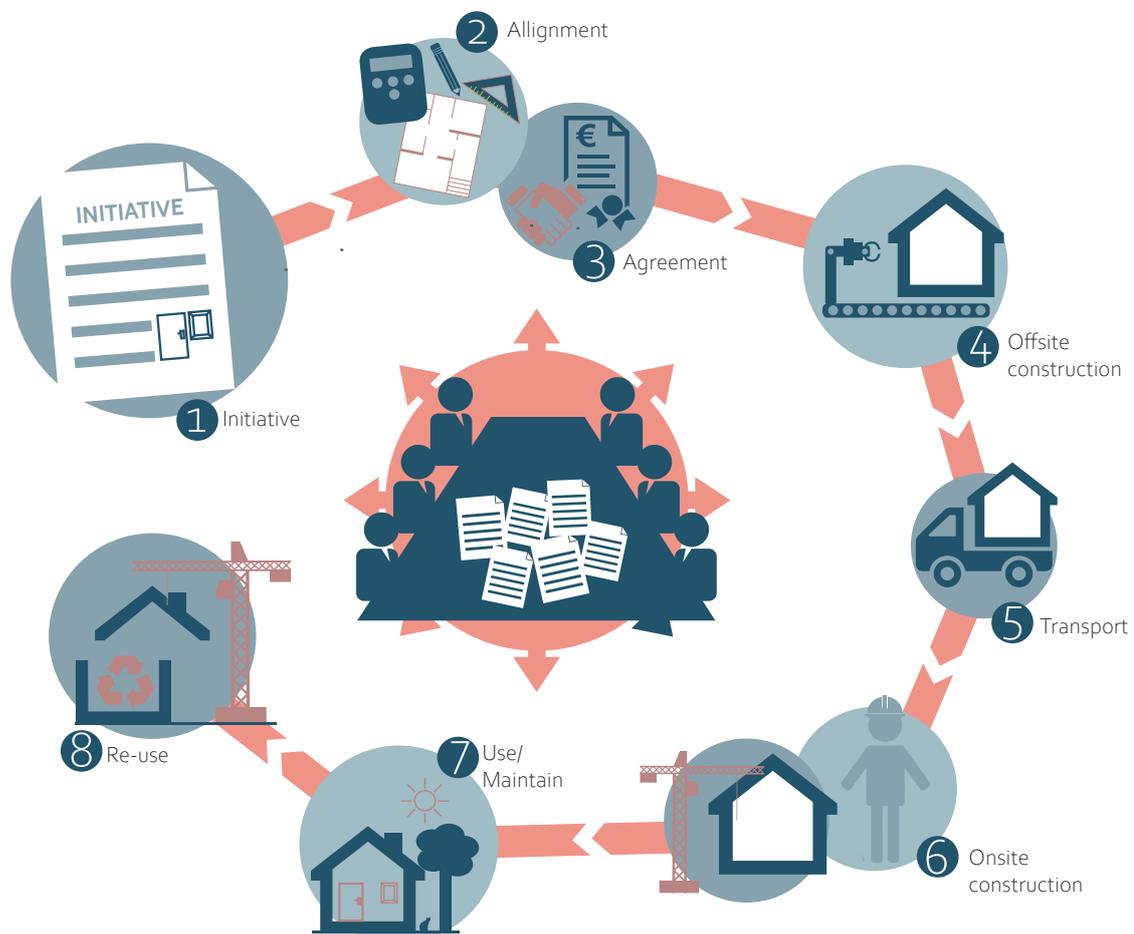


Figure 3.5 - Industrial process (own illustration by the use of ABN AMRO, 2015)

After the constructor and client have agreed on the design and all permits are obtained, the construction can start. Where in the traditional process, the final design is translated to BIM after everyone agreed. The industrial process makes it possible to design a house in a configurator automatically connected to a BIM model. Besides, preparation and procurement require much less time. The constructor works with standard material and elements and can therefore buy in advance without risk. If he does not use the material and elements, he can use them for the next project. In the industrial project, the preassembly is done offsite in a factory, whereafter the onsite construction combines the preassembled parts. Due to the offsite production, the onsite production time is shorter. This means that delivery time is much shorter, and residents can quickly move into their new home. In the industrial building process, an end-of-life phase is included. This phase consists of reusing and recycling building materials or components, which make the houses circular.

3.6 Current position

An earlier chapter elaborated on the benefits of industrial housing, but there is still a reason why the housing industry is lagging behind other manufacturing industries. This chapter will describe industrial housing's current position by elaborating on the factors that slow down the production process compared to other manufacturing industries such as the car industry. The housing industry is shifting from an onsite assembly to an offsite manufacturing process. Many other industries shifted to the manufacturing process a long time ago. The car industry is one of those industries that has undergone an inducing change and is now one of the most optimized industries. The housing industry is, therefore, often compared to the car industry. This industry has a standard production line for car manufacturing that is completely automated within standard variation. The housing industry can benefit from learning about advanced manufacturing techniques used in the car industry. However, there are some critical differences between the housing industry and many other manufacturing industries, making it challenging to industrialise. The limits of manufacturing relate to the stability of the market, cost of transportation and ability to control and subdivide labour on dispersed sites where final assembly takes place, besides fluctuation leads to hesitation among developers (Gann, 1996).

High start investment

For the industrialisation of the production process, a factory with associated machinery is required. An average construction company has around 11.100 euro worth of machinery and installations for each person working, while for companies with a factory, this number is around 115.000 euro (ING Economisch Bureau, 2020). The costs for companies to industrialise the housing production are practically identical for other companies that have industrialised. This means that construction companies that currently only operate in the traditional field must invest more than ten times what they are used to in machinery and installations. Besides, this investment is made in one go, which means that they must deposit the money at once. Construction companies hesitate and argue that they have to see a future market to make this investment (McKinsey & Company, 2019). Besides, this high one-time investment ensures that only a small number of companies can make this step.

Uncertainty in the future

As Gann (1996) described, the limits to the application of manufacturing techniques relate to the size and stability of the market. By this, he means that the size and stability of the market determine whether it is feasible to build in a manufactured process. On the housing market, there is currently a high structural demand for housing. This demand does not seem to change in the short term, but eventually, this demand will stagnate. It is difficult to determine when and how this will change. It is this uncertainty that makes it difficult for constructors to respond to the market. In one of the prognoses, the growth of the number of households slows down around 2070 (ING Economisch Bureau, 2020). As a result, constructors will face a shrinkage market, making it more difficult to recoup their investment.

Uncertainty in the demand

In every manufacturing industry, continuity is vital. Most markets have a secured, large and continuous market, which they could organise and control with success (Gann, 1996). A factory must always be running at maximum capacity; when a factory stands still, it costs a lot of money. Therefore, the continuous demand for a product is crucial for a factory, but a continuous demand is needed. For the housing market, this security of continuity is not there. This makes it difficult for industrial housing.

There is no continuity in the production process; thus, investments by construction companies are less likely to be made(Harsta, 2020).

Uncertainty available locations

The market's stability also has to do with the ability to control and subdivide labour on dispersed sites where final assembly takes place(Gann, 1996). One of the differences between the housing market and most other industry markets is that a house is landlocked. In most industries, it is possible to store parts of the production, for example, in the car industry. However, the final assembly of industrial houses takes place at the site; this means that a construction location must be available. The constructors must build on available land, but this availability of sufficient ground for housing can also play a role in the long term (van der Heijden & Boelhouver, 2018). The market is currently struggling to get land available for development. When a factory has a continuous production, there is also a continuous need for locations. If the market is not capable of getting a hold on enough locations, the production must stop.

Uncertainty with suppliers

The invention of mass-production with high volumes of standardised products was the start of a manufacturing process. Standardisation is the first prerequisite for a factory (Gann, 1996) and, therefore, an essential part of the housing market's industrialisation. Standardisation leads to more specific components. For example, where in a traditional process, a contractor could make a wall around every size window frame, in the industrial process, the frame should fit in the prefabricated wall. Therefore, the building materials are not specified in the traditional building process and can be supplied by multiple suppliers. The industrialised process uses standardised components; a specific supplier develops these components. This means that the constructor becomes more dependent on his unique suppliers, the security of supply is thus reduced(ING Economisch Bureau, 2020). Figure 3.6 illustrates this; in the traditional process, there are four suppliers that, for example, could deliver the window for a project. Only one supplier in the industrial process makes the windows that exactly fit in the premanufactured wall. If this specific supplier stops or the constructor has a higher demand than the supplier can supply, the constructor has a problem.

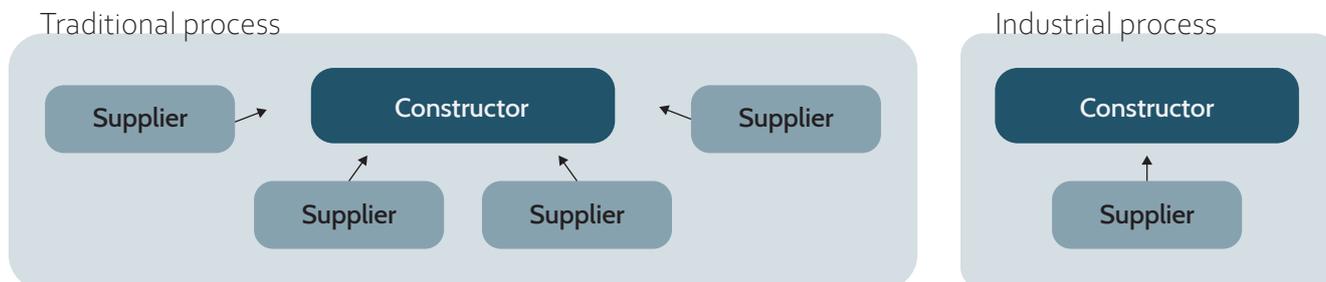


Figure 3.6 - Process suppliers (based on ING Economisch Bureau, 2020)

Need for change

Besides changes in the building process, industrialisation impacts the organisations that are involved in industrial processes. The changing approach of industrialisation will involve cultural and organisational challenges (ABN AMRO, 2019). Actors need to adopt a new way of working; their role in the process will change. Compared to other markets, such as the car industry, which is often perceived as the leader in management practices, the construction market is a traditional and stubborn industry (Gann, 1996). Besides, this industry depends on many different actors from different fields that all need to act. For most other markets, the changes only involve the manufacturer. There is less involvement of public parties, and the client is a private individual that wants to buy a product. The housing industry involves many actors that have a say in the project. The public parties have an active role, and the client is an organisation; both have their unique organisation and culture.

Challenges in the product

This research will focus mainly on the process and the different actors that are involved in this process. However, profits for the future can also be made in the product, and optimization of the product affects the process. The industrial house as a product can become cheaper in production and user costs. On sustainability, the houses can improve their material use and type of material. In addition, there is still

much to be achieved in the reuse and circularity of the products. Besides, variation is still a significant factor that leads to a discussion among clients and future residents. The fear that industrial products lack variety is strong. For the client, it is therefore of great advantage if a product has many variation possibilities in the appearance of the building. By offering more variety, constructors make themselves more interesting for the client, but this must be done without the loss of standardisation. The product's production process can also be improved; this means a higher production in a shorter time, thus more money.

The constructor is mainly responsible for developing the product, where there will always be a motivation to innovate. For the constructors, the innovation of the product is always a strategic trade-off between quality, cost savings and time savings (Figure 3.7). For the upcoming innovation, the trade-off will be made by innovating on the above points.

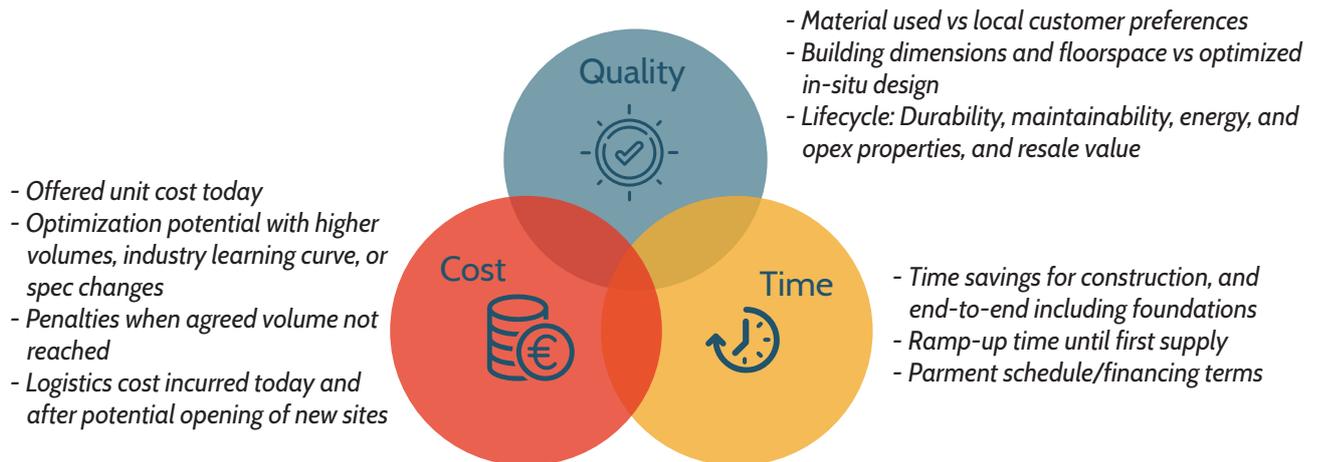


Figure 3.7 - Value creation for developers (based on McKinsey, 2019) reducing order lead time and creating variety with limited resources. In the construction industry, the implementation of modularity has been limited to off-site production (OSP)

04.

THEORETICAL FRAMEWORK

4. Theoretical framework

The theoretical framework forms the input for the empirical research to answer this study's main research question: *What adaptations are needed to scale up the Dutch production of industrial housing?* To answer this main question, sub-questions have been formulated to get an understanding of industrial housing. The theoretical review answers the first sub-question by the use of theory. This chapter gives an overview of the theoretical review by answering those sub-questions.

Scope definition

Q1 - *What is industrial housing?*

Scope: The result of combining developments in the production of houses has led to industrial housing. This research's scope definition is that an industrial house is produced in an offsite fabrication method to produce modular, manufactured and completely standardised houses. The result of this fabrication is not a concept but a final product.

Benefits of industrial housing

Q2 - *What are the benefits of industrial housing?*

- In the process: positive impact on cost, time, and risk
 - Reduction of construction time
 - The offsite production is not affected by external factors
 - Continuously optimisation
 - Reduced process time
 - Reduction of mistakes
 - Less risk
- In the product: positive impact on cost, quality, and environment
 - Improvement of the quality
 - Control of the quality
 - Consistency of the quality
 - Less construction mistakes
 - More sustainable
 - Waste reduction
 - Material passport
 - Circularity

The benefits of industrial houses in the product and process impact the five categories: quality, time, cost, risk and environment.

- I. Quality: The quality of the product improves; this includes a better control and consistency of the quality because products are factory-made
- II. Time: The production process time is reduced because the construction time is shorter, and the process time is optimised
- III. Cost: The optimised production process is more efficient in time and resources; this leads to a cost reduction of the product and the process.
- IV. Risk: Risk in the process is reduced due to the optimisation of the process and the fact that the product is constructed in a factory.
- V. Environment: The process and the product are better for the environment; this includes sustainability, reduction of waste, circularity and the use of a material passport

Actors in the process

The findings on the actors and the process help identifying differences in the process and the role of actors during the interviews by answering the sub-questions:

Q3 - How are different actors currently involved in the process?

Q4 - How does the current production process of traditional and industrial housing work?

The six actors explained in the theoretical research: client, constructor, suppliers, designer, public parties and financiers and their role in the process are illustrated in Figure 4.1 .

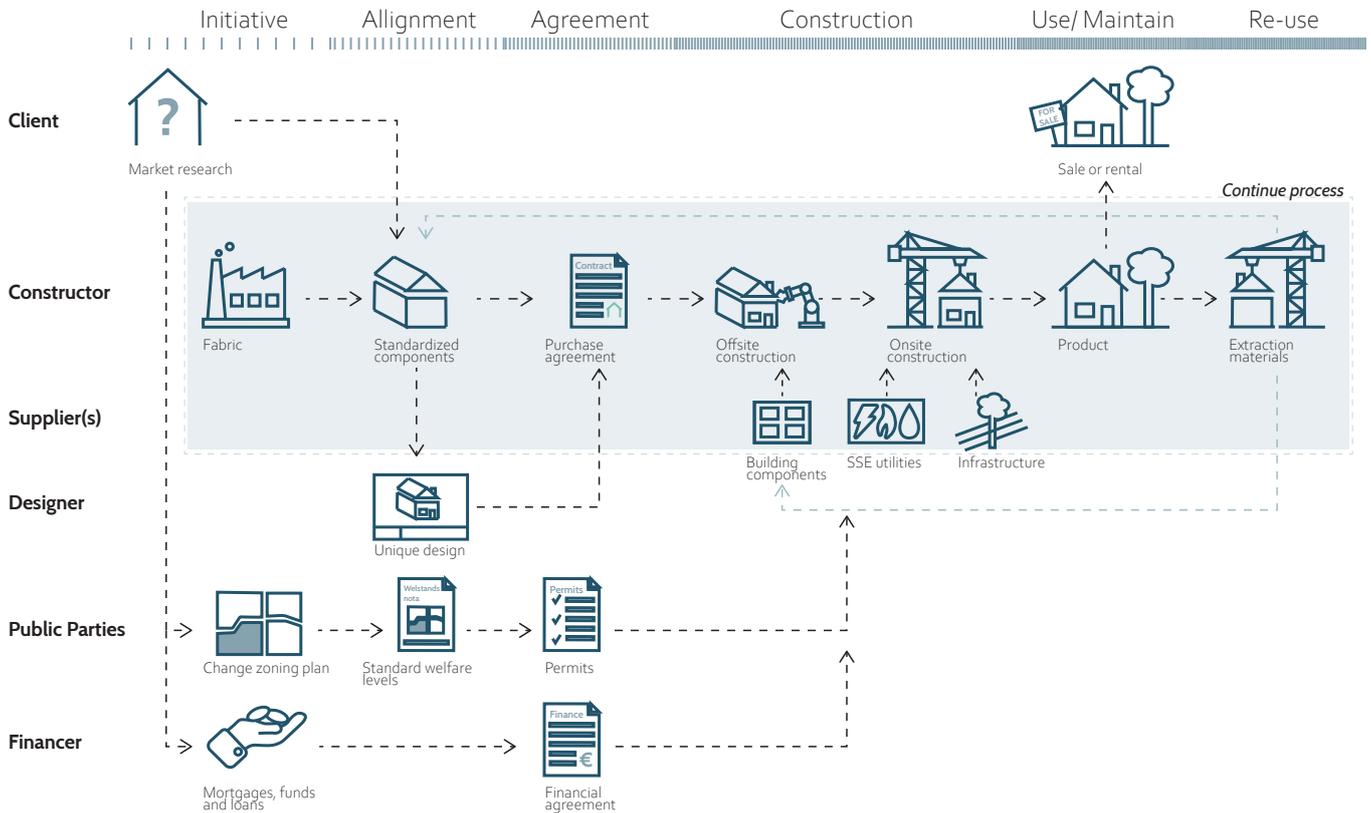


Figure 4.1 - First version industrial process

The sub-questions are answered in the illustration given based on the theory. These schemes give an overview of the industrial production process with the different actors involved in different parts of this process and can be compared to other production processes.

Opportunities and barriers

The current position of industrial housing is used to identify opportunities and barriers experienced by different actors involved in the production process. The theoretical findings give the first answers to the sub-question:

Q5 - What are the opportunities and barriers for industrial housing?

Current position

- High one-time start investment
 - Hesitation among constructors
 - Only a small number of companies have the capital to make this step
- Uncertainty in the future number of households
- Uncertainty in a continuous market demand
- Uncertainty available ground
- Uncertainty with suppliers

- Need for change.
 - Cultural change
 - Organisational change
- Challenges in the product
 - Use of new materials.
 - Variation in the product
 - Reuse and circularity

In the complete theoretical framework, different opportunities and barriers can also be found indirectly by using PESTLE as a tool. The result of this complete analysis can be found in APPENDIX I.

05.

EMPIRICAL
RESEARCH

5. Empirical Research

This chapter discusses the empirical research that is conducted and its findings. The results of the empirical research are divided into three parts: 1) The product, 2) The process, and 3) the project (see Figure 5.1). In each part, the findings will be explained first and then the conclusion of each part. The explanation of the findings gives the reasoning behind the conclusions.

During the research phase, the content of the empirical part developed. The first part about the product made it clear that the focus must be more on the process. Subsequently, during the second part of the research about the process, interviewees brought the example project to attention. The list of interviewees also developed during the interviews by interviewees suggesting persons with new perspectives.

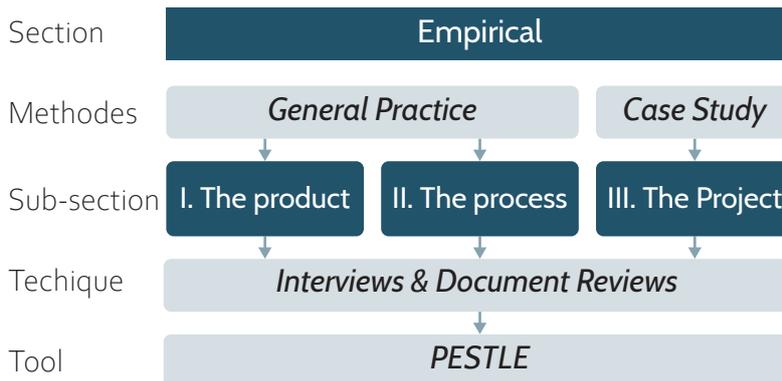


Figure 5.1 - Empirical research framework

5.1 Part 1 – Product

During the interviews, the first part focused on the products. Constructors who have developed an industrial product were questioned about their own product, while the other actors were questioned about their experience with products available on the market. It is relevant to mention that constructors that developed a product are one step ahead. Constructors have developed products that are not yet on the market or are not even finished. Besides, constructors are continuously innovating. This means that they are already working on the next innovation even before their product is on the market. This gives constructors more insights than other actors who only knowledge about the products on the market but limited knowledge on future developments.

Findings

Scope of the product

All interviewees were asked about their interpretation of industrial housing. This is asked to define a common baseline and definition of industrial housing, which is important to be able to compare their feedback on the industrial housing and experience with industrial housing.

In almost all the interviews, a factory was mentioned to explain industrial housing. The most common argument for a factory is moving the construction site to a factory. This means more offsite construction and a shorter onsite construction time. A factory means a factory-based approach, repeating, automating, and robotising in conditioned circumstances. Within the factory, the interviewees made one distinction: the product could be assembled standing still in the factory, an assembly line, or the product could move through the factory, a production line. Most interviewees see this second option of a production line as a further innovation.

Between the different actors, there were also differences within the explanation of the scope. For some actors, industrial housing is still a confusing term. Interviewee B7 answered on the question of what industrial housing is: 'That is a good question, and sometimes I do not understand it either.'. This answer illustrates that even actors who work in the housing market still lack clarity on this term. However, it also became clear that these parties care less about the degree of industrialisation, 'it does not necessarily have to be built industrial, as long as it is cheap and fast', 'for me as a client, how it is built does not even

matter that much' (interviewee B7).

On the other hand, the constructors that have developed a product have a clearer view of the scope of industrial housing. As said, the constructors have a better view of the future of industrial housing, which explains that they have a better view of the scope. In their explanations, the role of digitalisation is often part of the scope. Interviewee B4 explains this is the step from a tender specification to a manufacturing specification, where the manufacturing specification controls the factory.

Within an industrial produced product, a second distinction can be made between 2D and 3D elements as manufactured components. None of the interviewees said it had to be one or the other. However, constructors are more focused on this issue, while other actors state that it does not matter. For constructors, the differences between 2D and 3D are more of an issue because they have to transport the materials or modules to the site. Road transport has size limits; this means that 3D has more limitations in terms of transport than separate 2D elements. However, 2D elements need more finishing on the building site. Constructors are mainly focused on rooms with a high degree of finishing in the manufactured components. Realising finished rooms in 3D elements, think about installations, kitchens, and bathrooms lead to less finishing on site. In the interviews with parties other than the constructors, it became clear that there is still much confusion about conceptual housing and how this relates to industrial housing. Both terms are used interchangeably, while, as interviewee B2 said: 'Conceptual or industrial housing are not interchangeable terms' (see chapter 5.2 - scope of the process, for the explanation of the differences).

When looking at the variation in industrial products, interviewees are aware of the fear of the market that there is not enough variation. This discussion about variation leads to the question of how much variation is needed for the target group of industrial housing. Interviewee A2 argues that the houses are built for lower incomes and that they do not need many variations. From experience, he says that even when different variations are offered, the variants are never chosen. By not offering too many variations but only focus on fewer different products, the degree of standardisation can be increased. Apart from the product itself, there are therefore different opinion about the purpose of this product. The target group, which means the future residents for industrial housing, is one of the points of discussion found during the interviews. Besides the target group, the location of industrial housing is mentioned. Developing in an urban area is much more challenging than an expansion area. In an urban area, the existing urban environment must be considered; this means the residents live nearby and meet the complex environmental aspects, which can lead to conflicts (interviewee B3).

Finally, the current products on the market can be divided into stacked and unstacked houses. For constructors, the unstacked house is easier to realise, but meanly in urban areas, the demand for stacked houses increases. The supply of unstacked ground bounded houses is much greater, but the urban area needs more stacked houses (interviewee B7).

Benefits of the product

The five elements (quality, time, cost, risk, and environment) of the theoretical framework (CHAPTER 4) were found during the interviews. From the perspective of all actors, the focus is on time and costs, followed by quality and risk and then the environment. For the client and public parties, the costs aspect seems especially important when it comes to rental housing. If the product is more expensive, the tenant needs to pay the higher rent. The client is thus focused on the final costs of the product and sees cost reduction as beneficial. In addition, the client sees that the time to build must be reduced to meet the demand. Building more houses in a shorter time is therefore beneficial. Quality and environmental aspects are for them defined by regulations; the product must meet these regulations. Public parties that are responsible for the realisation of houses share the position of the client. However, within the public parties, responsibilities are divided. For example, the environment falls under a different division within the public system than the realisation of affordable housing. The interest in the five elements within the public system is, therefore, dependent on the division.

In the interviews, it was found that constructors are more focused on the result of using a factory to produce. Using a factory creates more possibilities in the product, faster production, fewer people involved in the production, increased customer satisfaction, and a better price (interviewee B8). The focus is on affordability and efficiency. As interviewee B15 explains: 'It is about a process that reduces costs with less risk and a higher quality'. The quality will become more constant with a factory, and the offsite finishing level will increase (interviewee B8). To conclude, the empirical findings describe the development in the product for constructors as a trade-off between quality, time cost and risk.

Opportunities and barriers of the product

Interviewees were asked about their point of view of challenges in the product. These findings are translated to barriers that hinder current optimisation and opportunities that can lead to optimisation.

One of the barriers that hinder every optimisation is restrictions and requirements imposed on a product. Additional or increasing requirements may lead to products that are no longer suitable. The possibility that increasing requirements make products unsuitable is disastrous for a manufacturing process where repetition is the basis. For industrial housing products, these additional requirements have two causes. First, requirements to make our environment more future proof are increasing. These are requirements such as energy use, emissions, and water use. For example, in 2022, the government will impose these additional requirements by means of the Act on Quality Assurance for Building (Dutch: Wet kwaliteitsborging voor het bouwen). Besides, there is also an increase in local requirements (interviewee B3). Embedding all local requirements in standardized products is complex.

For clients, another current barrier in the product is its rigidity, Interviewee B9: 'the product is rigid, if you make it in the factory, all the sizes are the same, it is standardised. This rigidity in itself is not the problem. Actors that work in the sector believe in its possibilities and see the possibilities in the facade. Besides, they understand that the majority of the households want the same plan inside their house. However, adaptability is the problem, interviewee B9: 'we should not think for the consumer, the house is what it is.', 'the big issue is, when you start building in a specific system, you cannot change the house itself anymore'. With this statement, the interviewee meant that it is difficult for the house owner to make changes, such as extensions. It must be noticed that this is only applicable for homeowners since tenants do not make significant changes. For homeowners, it is an investment to change their house; it makes their house worth more.

Besides the barriers, the interviewees also have highlighted the opportunities. A distinction is made between changes in the physical product and the system behind this product. The physical product consists of building materials, building systems and installation technique. As said for developers, there is always a drive to optimise their product; this also means the physical appearance. Interviewee B11: 'the product is developed and built-in large numbers, but so much more can be done with the product.'. Most of the products that are currently realised on a large scale are built in concrete. Part of the constructors indicates that they will not change this for the upcoming years. However, some constructors see a greater future for other materials such as wood. Other actors also see a future for new materials or are at least open to it. Another opportunity in the product seen by the interviewees is the optimisation of the space planning in a module. By optimising the space, the module can be used more efficiently. In addition, technical installations and the level of finishing can be optimised.

During the interviews, it became clear that there is much to be gained in the system behind the product. Achieving this optimisation involves digitalisation and robotisation in an intelligent system that involves BIM (building information management). This optimisation creates a win-win situation for clients and constructors, but also for the rest of the market. Currently, different actors use different BIM models; Figure 5.2 illustrates this. First, the client creates the house in a product configurator. This means that the constructor must have developed a digital house configurator for their product. Currently, most industrial products are not integrated into a digital house configurator (that is open to the client). When the client has made his decisions, the digital house can go to the future resident. This is only done when the future resident of the house buys the house; if the project is for rental housing, the clients make the final decisions. The future resident can make the last changes, for example, an extension or an extra window. Here he sees immediately what the extra costs are. When this step has been completed, the product will go to the constructor. The constructor will make a new adapted BIM model. This model includes architecture, constructions, and installations. With this model, the building plan and construction drawings are made. However, suppliers and the factory of the constructor work with different BIM models. This means that the model or construction drawings and building plans are translated to another new BIM model. By innovating and optimizing this process using BIM, it can become a linear process (see Figure 5.3). In this linear process, the client configures his products, and this model goes direct to the constructor. The contractor approves the model and is then directly linked to its construction and installations. This model is also a BIM model where factories can work with. The model goes to the factories of the constructor and supplier(s), and they can start constructing. In addition, after the contractor approves the model, a contract can be generated automatically with the documentation for the granting of permits.

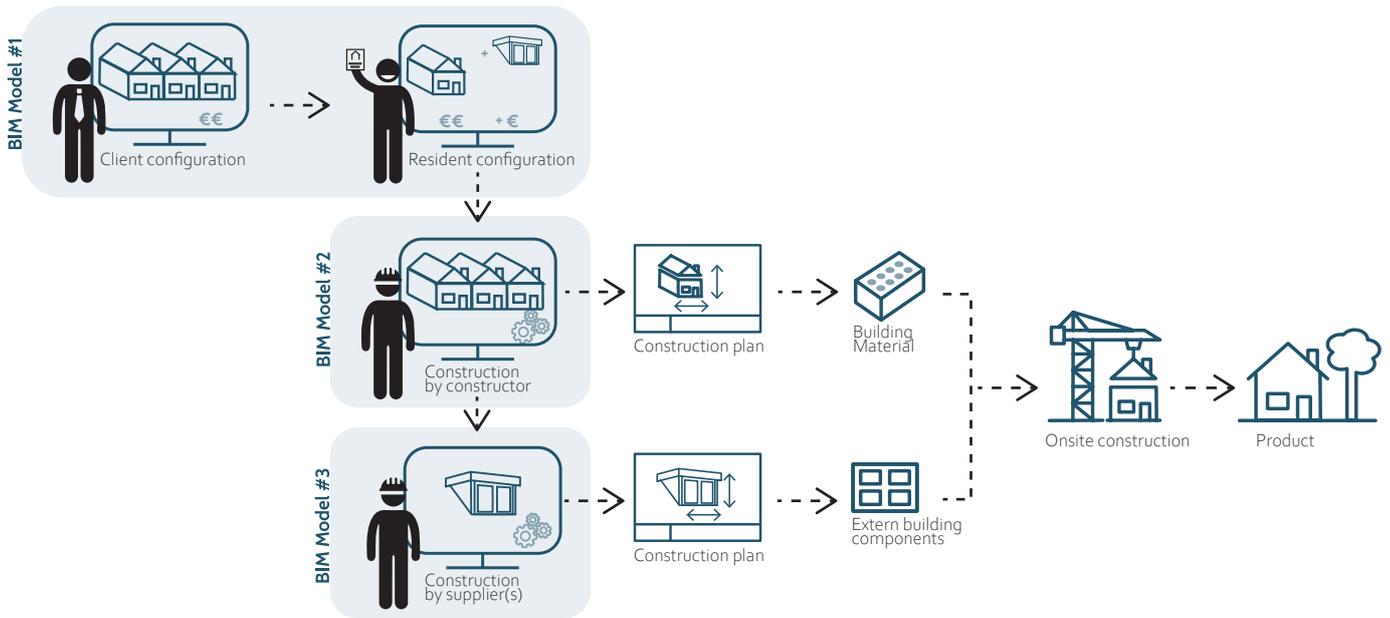


Figure 5.2 - Current use of BIM models (own illustration)

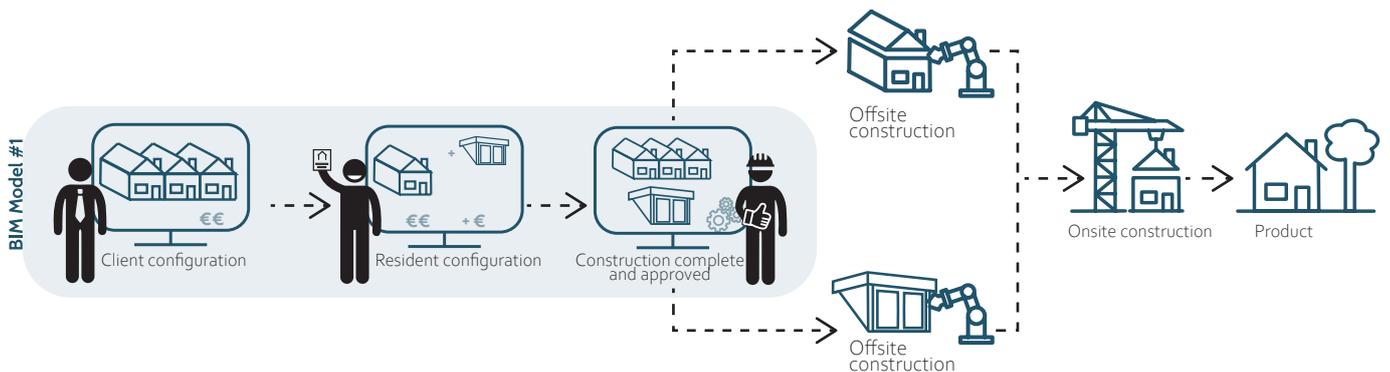


Figure 5.3- Optimized use of BIM models (own illustration)

Constructors see the potential to make this step, interviewee B15: ‘we are currently hard working on translating a BIM file to the factory’, during the interviews, the urgency became clear. Among clients, the demand for a house configurator is high. Interviewee B7: ‘Ideally, from my point of view... I would just like to see the price, click a few modules, number of floors and size. Click, click, click and then start constructing.’. For them, this step of optimization means a better insight into the market’s possibilities, with the benefits of a direct price identification. In the process part of the empirical research, the benefit of this optimization will become even more visible.

Finally, there is currently a residual value problem within the product. This problem means that a product at the end of its life can have a residual value. However, this is currently not yet considered by the market (interviewee B5). This residual value can become an opportunity in the future, but there are hardly any industrial products that reached the end of their life. Thus, currently, constructors are facing the barrier that they have no knowledge about the reuse of materials and their residual value. The opinion among interviewees about this residual value is diverse.

Interviewee B5 explains that there is no second-hand market for products yet and that constructors and suppliers could help if they could provide guarantees on residential value. Currently, constructors only assume the residual value of half products. While clients are very interested in purchasing for the residual values, this gives them more flexibility in the future. This freedom in flexibility helps them because they also do not know what the demand for the market will be in the future. If they can give houses back to corporations when they are not needed, this reduces the risk of overbuilding. Interviewee B11 explains that they can repurchase the components after their service time and already done this. However, he also explains that it is currently difficult to set on beforehand what the product is worth after its service

life. They know that they can do a lot with the used components, but the question is if there is still a demand for these components. Interviewee B15 clarifies that the agreement to buy back after the complete lifetime of a building is a huge risk for the constructor. It does not fit into a constructors financing model because the turnover they receive now after completion is essential.

Sub-conclusions

The market sees industrial housing as the industrialisation of the product and the process. The role of a factory-based approach (repeating, automating, robotizing, conditional circumstances) and innovation in the product (standardized variation, digitalization) is essential.

For industrial housing, it can be discussed:

- If the factory is a production line, an assembly line or can it be both.
- If the product consists of 2D, 3D-modules or a combination.
- If it is conceptual housing or industrial housing.
- What the target group is.
- What the location is.
- If it is a stacked, unstacked product or both.

The interviewed actors also mentioned all five beneficial elements (quality, time, cost, risk, and environment) of industrial housing. Between the different actors, there is a different interest in the benefits, and they also have a different degree of understanding the scope of industrial housing. The development in the product for constructors is a trade-off between quality, time cost and risk. Clients focus on the costs and see the quality and environmental elements as the responsibility of the public parties. The public parties cover all elements but in different divisions of the public system.

Barriers of the product given by actors in the field are:

- Additional or increasing requirements.
- The adaptability of the product
- Lack of knowledge about the residual value

Opportunities of the product given by actors in the field are:

- Material, space planning and installations
- Digitalization

5.2 Part 2 – Process

The production process of industrial housing involves multiple actors. In the second part of the interview, interviewees were asked about the role of each actor in the process. To make sure every interviewee was on the same page, the illustration from the theoretical framework of the industrial process was shown. Interviewees were first asked if they agreed with the process illustrations. Comments made by interviewees with a valid substitution are included in the illustration. This feedback on the illustration resulted in a few minor adjustments of the illustration during the interviews. Besides, during the interviews, it became clear that there was a need to compare the traditional with the conceptual and industrial process. The information of these processes was also collected during the interviews and put into a process illustration.

The interviewees were then asked about the opportunities and barriers of each actor in the process. During the interview, the question was first openly put to the interviewee. When the interviewee got stuck, the theoretical conclusion was used to steer.

Findings

Scope of the process

To give more substance to the industrial process, the traditional and conceptual process is also illustrated. This comparison shows the differences between the processes and the different roles of actors in these processes. The following processes are based on the assumption of an optimal progression in time. Unforeseen events that create delays are not taken into account. However, it may be assumed that the risks and unforeseen events in the industrial process are less likely to appear. The lead time of the industrial process is, therefore, closer to reality. Figure 5.4 shows the traditional process.

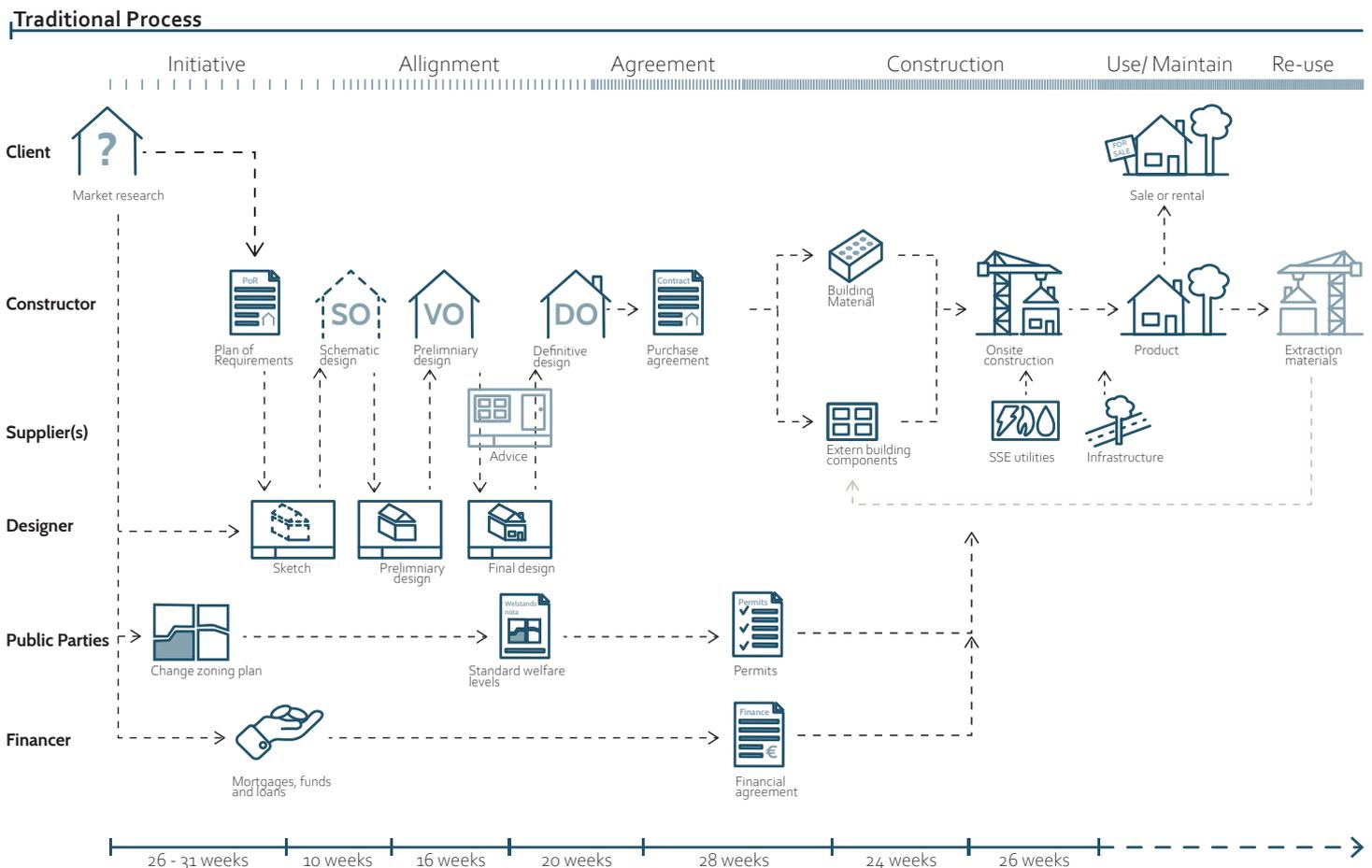


Figure 5.4 - The traditional production process (own illustration, time indication obtained from interviewee A3/B10/C3)

As said, some actors think that they already started industrialisation. They see the conceptual process as an industrial process. However, the conceptual and traditional process is almost comparable, only the lead time is very different. Besides, in the conceptual process, the steps in digitalization are partly made. The step made in digitalisation is not visible in the illustration but influences the shorter lead time. Figure 5.5 shows the conceptual process.

Conceptual Process

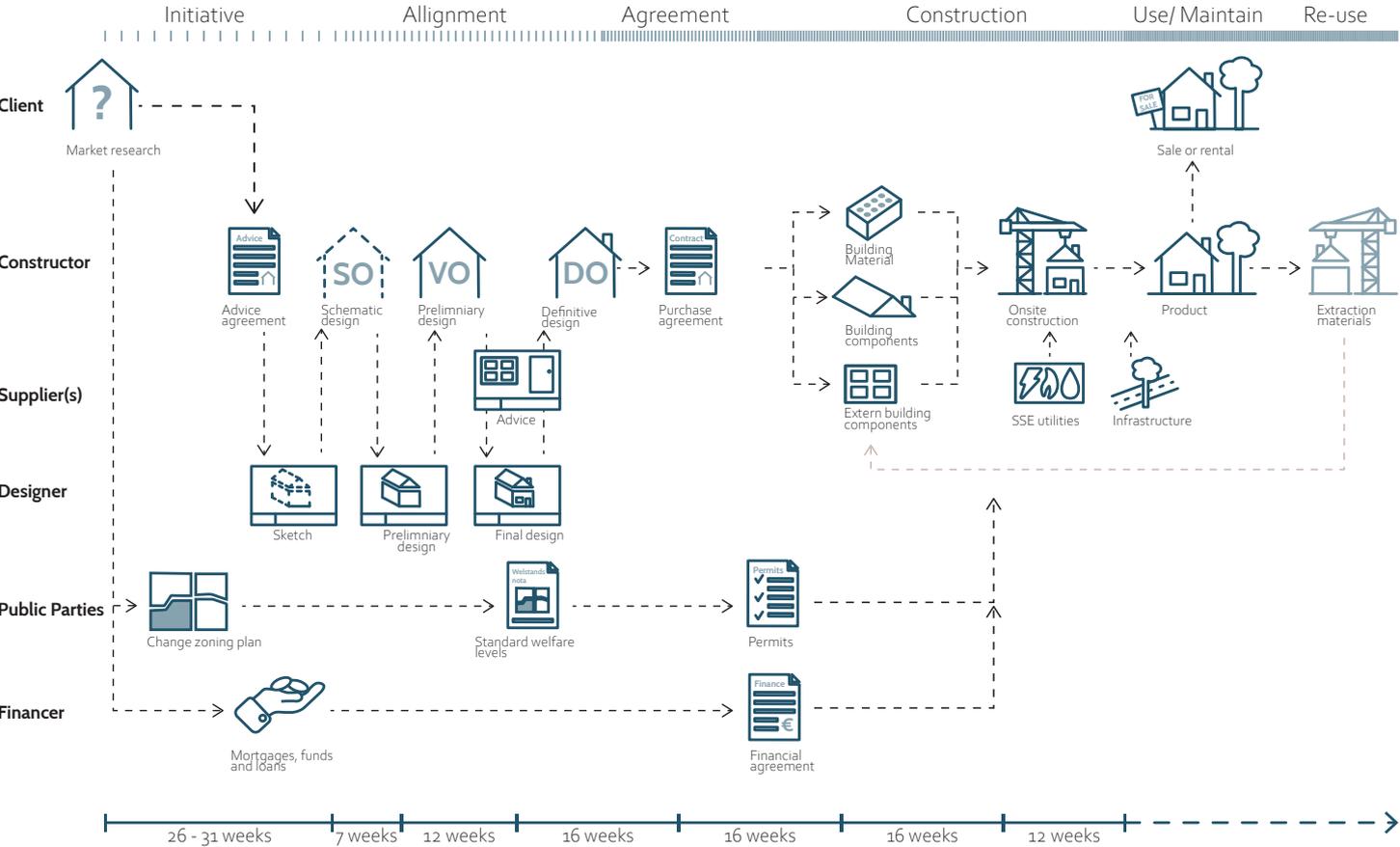


Figure 5.5 - The conceptual production process (own illustration, time indication obtained from interviewee A3/B10/C2)

The industrial process of the theoretical framework was explained to interviewees during the empirical research. Some changes are made in the illustrations based on the comments of interviewees (see Figure 5.6). Besides, the empirical research lead times of the phases were included.

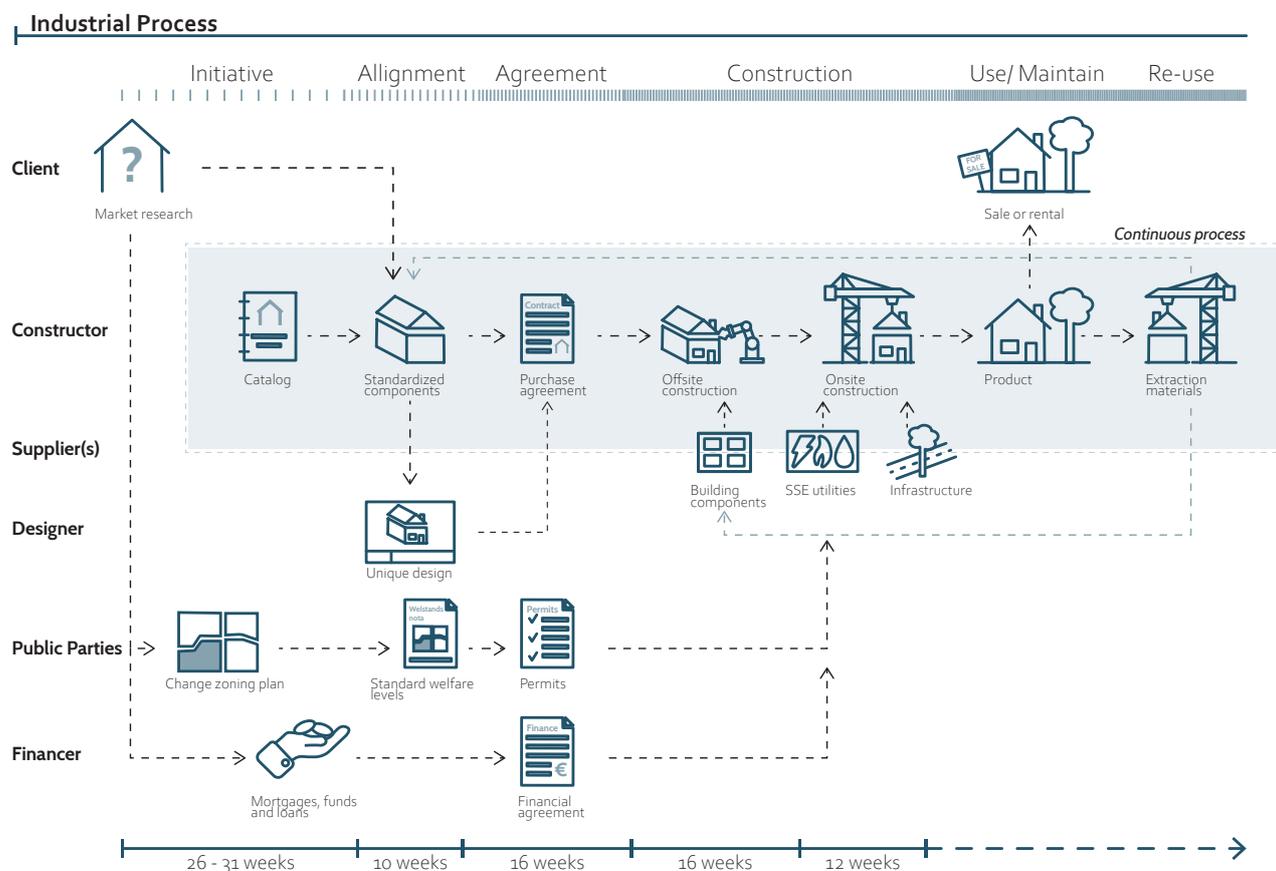


Figure 5.6 - The industrial production process (own illustration, time indication obtained from interviewee A3/B10/C2)

Opportunities and barriers of the process

The opportunities and barriers are divided into general findings in the realisation of housing and findings focused on the industrial housing process. The general findings are also experienced in a traditional process. For the industrial housing findings, the role of industrialisation has an impact. In addition, when the industrial process is optimized, the impact of general findings related to the process is relatively increasing in impact. Meaning that when the total time of the industrial process is brought down to the minimum, the impact of a general finding that takes much time in the process is now even more significant.

General findings

Even though the process illustration assumes a situation in which the land is already in possession of the client, multiple interviewees mentioned land positions. The market sees the demand for housing, and constructors see possibilities in their capacity to build more than they already do. Interviewee B8 explains that acquiring a land position is a major problem for many parties. He explains that they are often chosen because they own land besides the land which is in possession of the client. The client then suggests that we build the building on their land if they may build houses on our land (interviewee B8). Constructors see a risk here in the continuity of a factory because not enough ground positions mean not enough space for their products. For clients, a project starts with a land position. When they do not possess the land, they cannot develop. For housing corporations, this is even more complicated. They can invest in ground positions, but especially in urban areas, this is hardly done (Buitelaar et al., 2009). The other option is to develop on the ground that is in possession of the municipality or another party. As a housing corporation, you are then already one step behind, you will have to negotiate; ultimately, it is the politic who decides how many social housings there will be (interviewee B7). Interviewees often make the link between politics and the current situation around land positions. Assuming that more housing is a priority to the government, ground positions are a must, and a centralised government will

help create more ground positions.

A centralized government leads to another common point of discussion and disagreement. Interviewees are critical when it comes to the political approach to housing. The role of municipalities in the realization of housing has increased, but interviews indicate that this task is not the municipality's responsibility. This is mainly due to a desire from constructors for national guidance and regulation, focusing on the long term instead of four years. In the last years, the government is mainly focusing on sustainability goals; this is reflected in energy, gas, and emissions regulation. Besides, politicians focus their vision on the four years in which they were elected. After four years, there is a new election, and which can lead to complete new visions. Those additional regulations mean that constructors must make adaptations to the product that they have developed. Making these adaptations is especially a problem for a product-based production, where constant repeating is key.

Besides the lack of central governance, the functioning of local authorities is criticised. This criticism has grown in the last years because the role of the local authorities is becoming more important, while confidence in this party is declining. Among others, interviewee B8 explained that it is frustrating that projects are rejected on minor issues while it is said that we need thousands of new houses. Putting the control in the hands of local authorities has shifted the priorities. Interviewee B15: 'What is the dominant role of welfare and urban development? When you look to the crisis in 2008, the focus was not on urban planning and welfare because there was a need for housing; it had to be as cheap as possible.'. Interviewees all agree that quality is important, but now each municipality has its own unique ambitions. For those unique ambitions, the same barrier occurs when national regulations are changing, the product does not fit all unique ambitions. The moment you have all kinds of local interests that contradict each other, it will no longer work (interviewee B15).

Within these local ambitions, the standard welfare level is often cited as a barrier. Interviewee B4 raises the discussion about whether the system is a barrier or how the system is enforced. The welfare levels are there to stimulate us to build a pleasant living environment. This goal in itself is not a problem, but it should not cause unnecessary delays because people within the system are too ambitious. Interviewee B4 argues: 'then you should not intervene on the system, but you should intervene on the currently not functioning people within that system.

The main barriers that occur due to local ambitions are delays and slow procedures. Another delaying factor in this process of procedures is input from the public. Among others, interviewee B8 raises the discussion about the role of public participation. In the Netherlands, every private individual has a saying about every level of detail in a construction project. They have six weeks after the municipality grants permits to make their objections. With objecting, individuals can delay a project for years. Interviewees are not against public participation, but it has to be weighed against the social interest. It is sufficient for individuals who are harmed to look at what is fair; you could also say increase the damage cost a little but give them less participation (interviewee B8).

Another critic on the procedures and the building system in the Netherlands is its complexity. The system has become so complex with all its producers and regulation that even for citizens, it is difficult to understand the system (interviewee B14). Due to this complex system, it is not only complicated to implement, but as an actor, you are also at greater risk of making mistakes in the process (interviewee B14). These mistakes are contested, which can lead to delays. So, the more complex the system is, the more chance there is of stagnation in the construction process.

The last issue mentioned by interviewees is the changing labour market. It is already mentioned that after the financial crisis, the building industry reached an all-time low. The interviewees still see the loss of capacity and knowledge in the lack of craftsmen. The shortages of craftsmen are substantial; with the outflow, many people left the construction industry who will never come back (interviewee B8). This means that we will have to industrialise due to the housing shortages and changes in the labour market because we simply will not have people who can do it (interviewee B15).

Industrial housing findings

The problem definition stated that every actor needs to act to make the transition. During the interviews, it became clear that actors are still mainly operating in the traditional system, 'we have all been brought up in the traditional process'(interviewee B4). Their internal organisation still works with procedures that fit in the traditional process. At the same time, the whole market realizes that it cannot longer go on like this; we are at the tipping point (interviewee B4). The construction world will have to move with a

cultural change to a new way of building (interviewee B3). Actors will have to make the transition to fit in the industrial process, and their role will change.

The client is the actor that needs to believe in the product to buy it. However, in chapter 5.1, it already became clear that clients have difficulties defining what industrial housing is. This barrier is also often mentioned by the interviewed constructors. Multiple clients have no idea what an industrialized product entails; this is fatal (interviewee B8). This lack of knowledge results in the client being very much focused on project-based thinking rather than product-based thinking (interviewee B3). Clients need to understand that they can buy a product that solves their problem (interviewee B11). Due to this project-based thinking, they do not always involve constructors in an early phase. As a constructor, you want to be involved in time because this is necessary for any industrial constructor (interviewee B4). Another difference between a project and an industrial product is the financial side. Clients often do not know that buying an industrial product includes all costs (interviewee B11). In projects, they are used to calculate an extra buffer in advance to cope with unforeseen events. For industrial products, the risk, thus the probability for an unforeseen event, is much lower or does almost not exist. Interviewee B11 explains: 'We have no failure costs because everything is monitored, everything is in processes, everything is controlled, and we meet our planning.'. Clients must also take this into account when they consider an industrial product versus a traditional product.

Besides, clients need to understand that an industrial product demands a different role from the client. Clients are used to designing their own house and like to create beautiful projects by themselves. They are hesitant to hand over the design work while it can give them the opportunity to save a lot of money (Interviewee B3). Interviewee B4 explains that he sees a shift in the role of the client. The client mainly wants to be relieved of his worries; he wants to be told what it costs and what he gets. Clients do not know how the client role works in industrial housing; constructors try to help them fill in this role (interviewee B4). This shift is already visible among clients. Interviewee B9, a project developer and thus client, explains that they are trying to change their internal organisation to fit the new process. They see the industrial house as a product: 'You fit the product, you know what it costs, and you know what the costs of the land, why should you develop your own project? It is ready, and we are taking the product off the shelf' (interviewee B9).

However, if the client is a housing corporation, there is even a more significant shift to be made. Housing corporations draw up a plan of requirements that they present to the constructor. The barrier lies in this plan of requirements. Plans of requirements are designed to fit the traditional procedures, while an industrial house has other variables. They stick to their plan of requirements, while these plans are very outdated (interviewee B8). This results in an enormous mismatch in how actors approach each other efficiently. The corporation must have a straightforward question, and the constructor must deliver a good product; this is currently not a linear process (interviewee B3). Interviewee B7 argues that the housing association does not necessarily have to change the product if the product is good. However, he does recognise this, 'sometimes there are small things that we still demand, for example about the tiles, crane of installations in the building'.

Besides the shift clients have to make in their role and the way they think about industrial housing, the current market does not make it easy for them. The market fragmentation is enormous, the number of parties working in the construction industry is gigantic. There is no sector that works like this (interviewee B5). This fragmentation has to do with the fact that the construction sector has a very low entry threshold; you buy a hammer and start hammering (interviewee B15). If a consolidation process takes place where the number of suppliers is reduced, this will be beneficial for clients (interviewee B5)

Constructors are responsible for the realization of housing products and will continuously optimise their product, but this new product means adaptations in the process. A critical facility for an industrial process is the building of a factory. For constructors, this is a crucial consideration between entry costs and the minimum number of houses required to cover the costs (interviewee A1). To build a factory you need two things, a vision and money (interviewee B8). Smaller constructors will not immediately have that capital, and if they do as a family business, then it is unlikely that they will take a 15 million euro risk for a factory (interviewee B8). In addition, this new factory requires new knowledge, Interviewee B15: 'I need people who simply know how to build a factory, so you have to realise that you have the expertise'. A constructor will therefore have to acquire this knowledge. Interviewees who have already realized a factory state that repeating this process for a second (or third) is more manageable.

Besides, within the process, constructors are responsible for selling their product to the market. This

means that they must make their product transparent and understandable. Interviewees that operate on the client side indicate that it is difficult to understand the large offer of products on the market. At the moment, much time is lost in getting the correct information, and often you have to contact each contractor individually (interviewee B7). The perception of industrial products is not good; this is a task for the marketing and communication departments of the constructors (interviewee B5). In addition, this clarity must also be improved internally, and employees must know what these products mean for the company (interviewee B15).

The general findings elaborated on the procedures and steering influence of the public parties. These factors are barriers and opportunities within the general building system. For the industrial process, interviewees indicate that there is also a lack of knowledge about industrial housing among public parties. This lack of knowledge leads to the fact that public parties are not ready for this new industrial process. Industrial housing demands a different way of steering, but municipalities still see every project as unique, where you must take everything into account (interviewee B3). This while industrial housing makes it possible to make the permit procedures easier. Standard products can help in simplifying the assessment of several products at the same time. Standardisation in the procedures means that customised contracts are no longer necessary. Instead, you get standard contracts for industrialised products (interviewee B5). To achieve this, there must be made better agreements with municipalities in advance (interviewee B7). It would help if municipalities would sit down with corporations and constructors and make some clear agreements in advance (interviewee B3). Difficulties in these standard contracts will be the extra requirements on top of legal requirements. The municipality should make a reasonable assessment here, for example: 'What is really more important, the colour of the balcony or that people can live there?' (interviewee B14).

For the realization of a product, most constructors involve suppliers to build parts of the product. Constructors call these parties co-makers. For an industrialized product, a co-maker should innovate along with the product. Not all constructors are currently focused on the production process of their co-makers, while on the other hand, in some cases, constructors select a co-maker because they are already further (interviewee B4). By working together with co-makers that are further innovated, constructors can learn from their co-makers (Interviewee A1). It is a possibility to first work together with a co-maker to continue developing by yourself (Interviewee B15). In general, constructors are positive about their cooperation with suppliers, but this can be attributed to the fact that they select these parties themselves. A supplier they can hardly choose for themselves are the public utility companies (dutch: nutsbedrijven). This branch is too widely branched and therefore unpredictable (interviewee B14). In addition, they are criticised for not keeping up with the time (interviewee B3).

All barriers and opportunities within the actors that are involved demand a cultural change within the organisation. Interviewee B13: 'we need cultural change, both inside and outside the organisation'. Interviewees all agree that cultural change is more or less necessary, but therefore everybody should be on the same page. 'If you really want to get something done, it is not about having the best idea, it is about thinking of a way to bring other people along, to stimulate and enthuse them towards the new idea, and what you often hear is that there is resistance to the new idea. That is utter nonsense because there is no resistance to new ideas, there is only bad guidance' (Interviewee B4). The difficulty of these cultural changes lies in fear of market parties. They are hesitant because there is the idea that they will become redundant in the industrialised process, mainly for the craftsman. Clients have project developers, leaders, managers, and purchasers employed, and they see this as a threat because their work consists of unique projects instead of buying a product (interviewee B5).

Sub-conclusions

Comparing the traditional, conceptual, and industrial process shows that actors are given different roles, and ultimately much time is won.

General findings

- Not enough ground positions are a problem for every actor in the field.
 - Risk in the continuity of the process
- Need for a centralized government with national guidance and regulations with a long-term vision.
 - Help with creating more ground positions.
 - Additional regulations are a risk for a product-based production.
- Public participation in every level of a construction project
- The system to build houses is complex.
 - Citizens do not understand the system.
 - Difficult procedures create hold-ups in the process.

Industrial Findings

Client

- Confusion and misunderstandings about industrial housing
 - Lack of efficiency between client and constructors
- Project-based thinking instead of product-based thinking
 - Contractor not always early involved.
 - Not aware of the financial benefit of the industrial product.
 - Hesitation to hand over work.
 - The plan of requirements does not fit in the industrial process.
- Fragmentation of the market makes it complex.

Constructor

- Crucial consideration for building a factory.
 - Need for enough capital.
 - Need for new knowledge and experience about a factory.
- More transparency in shelling the product to the client is needed.
- Internal capacity and understanding of industrial product.

The public parties

- Lack of knowledge about industrial housing
- Need for a different way of steering.
 - Change in procedures, more standardization.
 - Better agreements in advance

Suppliers

- Suppliers working together with constructors leads to innovation.
- Public utility companies are unpredictable and not keeping up with time.

All

- Cultural change is needed.
 - Stimulation and entuse them for new ideas to overcome resistance.
 - Hesitation to become redundant need to be overcome.

5.3 Part 3 – Project

In the third part of the empirical research, a case study was performed on a project in the Urban area of Eindhoven (dutch: Stedelijk Gebied Eindhoven - SGE). A building flow was set up in cooperation between Aedes and the NCB (Network Conceptueel Bouwen). A building flow is an initiative that stimulates corporations and actors in the construction chain to create a continuous and predictable demand (Aedes, 2020). The theoretical framework explained that a factory must always be running at maximum capacity. Constructors expressed a need for an increased demand to let the factory continuously running, after which the market started to consider cooperation (Doodeman, 2021). The urban area Eindhoven is one of the frontrunners in creating a corporation in a building flow and is, therefore, an interesting pilot project.

In the third part of the empirical research, actors involved in the developments concerning the case study were interviewed. Interviewees were first asked about their knowledge of industrial housing. They first explained the process from their perspective and then questioned opportunities and barriers in this process.

Findings

The project

In 2018, housing associations started to have problems with the ground prices in the area. They informed the municipality that they had to lower the prices because otherwise, it was impossible for them to realise social housing. The municipalities responded that it was not possible to lower these prices. They had invested in the ground, prepared it for building and had to pay interest. However, they were open to looking for other possibilities to make social housing more affordable. Together they started to look for possibilities to create a good and affordable product. (Interviewee B14)

In 2020, thirteen housing corporations and nine municipalities of the Eindhoven Urban Area had joined forces in a cooperation to create a plan for standardised housing. The cooperation aims to lower construction costs, accelerate the construction process, resulting in affordable, sustainable, and social housing available to tenants. The final goal is to reduce the shortages on the housing market and answer the demand for affordable housing. At this stage, they also involved the independent advisory bureau, Brink, as they realised that with so many actors contributing, an independent actor should lead the cooperation (interviewee B5).

Together with Brink, they decided to create a building flow with a purchasing cooperation of a standard terraced house. Interviewee B5 explained: 'We did not set any requirements to whether it had to come from a factory or that it was built in another way, we left that all open.' This decision was made to see what the market was capable of. Besides, for the client, it did not matter how it is produced. The contract has been put out to tender traditionally, using the competitive dialogue in the procedure. A competitive dialogue differs from other procedures in the manner in which the request is made, with a question for which there is no known. The clients use the solution submitted by contractors to conduct a dialogue that optimises the request and offer; a successful dialogue leads to an optimum solution (Rijksoverheid, 2009). Initially, a ground bounded house was chosen to request, but in the process, a compact stacked variant was added (interviewee B5). The final tender consists of the right to buy houses of a certain quality at a defined price but without the obligation for the housing corporations to buy the houses (interviewee B5). After an open and transparent procedure, the contract went to Heijmans and BAM Wonen. They have been given the task to build 200-250 houses in the next five years. The thirteen housing corporations signed this agreement with Heijmans and BAM Wonen.

There is no official contract between the corporation, municipality, and constructor, but multiple agreements have been made. The first agreement is that houses with the same technical specifications are tested only once. If a house is always the same, you can test it ten times, but you can also test it once (interviewee B14). Therefore, it is agreed that everything that we only need to assess once is also only assessed once (interviewee B5). Besides, the municipalities agreed they would critically look to improve the planning procedures; an extern actor is assessing the zoning plan procedure for obtaining building permits and how to optimize this (interviewee B14).

The benefits of the project

General building flow

The importance to create confidence in a building flow among clients became clear during the interviews. It is a promising prospect for the clients because they get a good housing product for a lower price than if they had tackled it traditionally (interviewee B3). Constructors interviewed were generally not yet convinced about the use of a building flow. They commented that it might help but not see it as a necessity. Some interviewees argued that they already have a constant demand and that separated small numbers are also sufficient. However, interviewee B15 also said: 'These may be developments of which you say, bundling of housing demand for the next few years to make a production flow will bring money, also for the corporations'. With more certainty about the demand in the upcoming years, it is more interesting for constructors to invest in industrialisation.

Case-specific

At the beginning of the process, the municipalities and housing corporations started to look at the task together. At this stage, no constructor was involved yet, but an independent advisory party was. In some building flows, a constructor is also involved in the process right from the start, this the situation in Eindhoven (interviewee B5). Together they defined what a good product was for them, and they found a product that met the common requirements of corporations in terms of the quality of the product (interviewee B14). By involving the municipality and the housing corporations in defining the product, every actor supported the defined product. This support for the product has the benefit that aldermen said they would work hard to eliminate unnecessary product requirements because now they understand what the bottlenecks are (interviewee B5). During this process, housing corporations realized that they have common goals and no longer saw each other as competitors. During a hold-up in the process where there was confusion about the roles and the responsibilities, it was simply smoothed over due to the excellent cooperation (Interviewee B14).

Another feature of this process is the open procedure with the competitive dialogue. The decision for an open selection was made because many parties are involved due to the cooperation of multiple municipalities and corporations. Every individual has his own network. By not selecting constructors, we do not put individuals in the position that they must explain their own network how the selection is made. With this decision, it is a transparent process with also the possibility that constructors will come forward that otherwise might be overlooked. During the procedure, every means to share knowledge between actors in the field was used. Even though the constructors were competing, they all presented their product. Step by step, the potential for variations in the industrial product was shown, and the support grew. This process has led to the removal of resistance and the misperception of uniformity on the part of the municipality. At the same time, the corporations realised that they should give the market volumes so that the market could innovate their products. The early and continuous dialogue between constructors, the municipality and housing corporations about the specifications were essential in this process. The housing corporations were prepared to make concessions if it meant a more standard and industrialized product. The dialogue made it possible to move towards each other. (interviewee B5)

Opportunities and barriers of the project

This project is a pilot project, where the first steps are made, and therefore also the first lessons can be learned. The most important factor that interviewees mentioned is the cooperation and trust between actors. Once the corporations are used to work this way, the trust between the municipalities and corporations that a building flow will work is created (interviewee B14). In the setup of this cooperation, you have to think carefully when you are with so many parties, and not everyone can take the lead; you have to make choices (interviewee B5). In the urban area of Eindhoven, they decided to involve an extern advisory party to help with these decisions. From the view of the advisory party, it is essential to take the time to create this building flow. Interviewee B5: 'there are so many actors involved that you have to get them all behind your plan and aligned. In addition to this, interviewee B14 argues: 'it has a lot to do with human commitment; if people believe in it, you will come a long way'.

Cooperation between actors is a barrier but can become an opportunity. Discipline is the most important; hold each other accountable and not let everyone become their own separated island again. Interviewee B15 comments on discipline in the process of Eindhoven: 'I think that is the greatest vulnerability. I am not saying that it is now because, after all, we have just started.'. To build trust and create a good cooperation, change will have to be made in small steps. Interviewee B5 explains: 'try not to take such a big step at once because that makes the chances of not succeeding quite high'. In Eindhoven, he

explained that an attempt had been made to take a big step, but not one that achieves the final goal. In different phases, cooperation will be created. Here it is essential to invest in an extensive preliminary process (interviewee B5).

In the urban area of Eindhoven, there was no purchase obligation for the corporations. An agreement without the obligations was the maximum that could be achieved (interviewee B5). However, later in the process, it became visible that municipalities also tried to make agreements for a more streamlined process. Suppose the agreement for a minimum purchase obligation would be set up on the front. In that case, the price would be better. With a purchase obligation, constructors have the certainty which will allow them to invest in innovation. Ultimately parties would make investments to innovate the product and the production (interviewee B5).

On the side of the municipalities, more efficiency in the procedures and permitting would be the next step. It is challenging to standardize factors related to the location. Location-specific permits will always have to be re-examined. However, municipalities can standardise more in the descriptions, procedures, and legal titles to create more uniformity in the process (interviewee B14). The product-specific assessment offers many possibilities to improve these processes. This means that when a product does comply with all building regulations and the building decree, and it is built again on another location, those product-specific elements do not have to be examined again (interviewee B14).

To conclude, interviewees were asked about what the next step might be for a new building flow. This question is answered on the assumption that the currently planned cooperation continues to run smoothly. This project is a pilot project, and if it processes to be successful, it is the first step to organise this permanently (interviewee B14). The next step would be to focus on industrialized products (interviewee B5). In this call for a tender, there were no restrictions and requirements for how the product was realised. However, it was assumed that industrialisation is necessary to obtain the most affordable product. With more focus on the industrialisation of the product, the market is stimulated to innovate.

Another suggested next step is a better alignment in the procedures. 'Suppose you streamline the actual building and production process parallel with the zoning plan procedures and the environmental permits. You can achieve an optimal process in that case, for this alignment on a regional level is needed' (interviewee B14). To achieve this, corporations and municipalities must communicate with each other on a regional level to create a constant demand and start their intern procedures at the right time.

Sub-conclusions

The process

In the urban area of Eindhoven, thirteen housing corporations and nine municipalities joined forces to create a plan for standardised housing. The first step was to create a building flow in a cooperation to purchasing houses together. A traditional tender with a competitive dialogue was put on the market. Finally, an agreement was reached with BAM Wonen and Heijmans to purchase a product for a fixed price and quality without any obligation.

Benefits

General building flow

- Confidence in the industrial product
- Certainty about the demand in the upcoming years
 - Certainty to invest in innovation for industrialisation.

Case-specific

- Early cooperation between municipality and housing corporations
 - Actors all stood behind the defined product.
 - Actors realized they have common goals and no longer saw each other as competitors.
- Open procedure with the competitive dialogue.
 - Transparency to constructors on the market
 - Exchange of knowledge by constructors
 - Growing support for industrial housing on the side of housing corporations and municipalities
 - Possibility to talk about concessions to realise more standardization.

Opportunities and barriers

- Create cooperation and trust.
 - Changing in small steps
 - Extensive preliminary process
 - Make choices about the division of roles.
- Optimize procedures and regulations.
 - Purchase obligation to stimulate innovation.
 - Automated product assessment for same products
 - Standardized location-specific permits
- Focus on industrialized products.
 - Stimulate the market to innovate.
- Streamline building, production, and procedure processes.
 - Cooperation between corporations and municipalities on a regional level

06.

SYNTHESIS

6. Synthesis

This chapter combines the findings of the empirical research. These findings are translated into recommendations. The recommendations were presented to an expert panel for validation. The result of this chapter are the recommendations with the comments of the expert panel that lead to the final conclusions.

6.1 Combined findings

The overview of the empirical research is combined in appendix IV. This has been done for each part of the study, theoretical and empirical for the product, process, and project. The findings are divided into strengths/opportunities and weaknesses/threats. To make them comparable, they are labelled with the categories from the PESTLE and the responsible actor. The findings from each different part are compared to each other and within the division that is made.

6.2 Recommendations

The combined findings have led to five main recommendations. These recommendations focus on the different parts of this research (product, process, and project) and the main actors (client, constructor, public parties, and society). Not all recommendations are directly derived from the findings. These not directly derived parts are mainly added to provoke conformation or refutation during validation by the expert panel.

Besides, the recommendations focus on the main actors in the process, while some actors can be divided into different scale levels and motivations to industrialize, which means that different actors under the same main actor can have different goals. When possible, the scale level and motivation will be addressed in the explanation of the recommendations and the conditions to succeed.

Product innovation

The first recommendation is focused on the product. Although the research is focused on the process, the optimization in the product has a beneficial influence on the product and the process. The theoretical framework discusses the benefits for the product and the process whereafter they are divided into five categories, cost, quality, risk, time, and environment. The constructor develops the product and is, therefore, the responsible actor. The theoretical framework described the current position of industrial housing and associated challenges in the product as a trade-off between quality, cost, and time. During the empirical research, it was found that constructors have a strong intern motivation to optimize cost, quality, and risk. This trade-off is the value creation for the constructors; they will always strive to optimise their product. Only the category environment is not covered in the strive for optimization among the constructors. The theoretical and empirical research did not precisely find the same categories. In the theory, time is an important benefit, while during the empirical research, constructors mentioned that it is not a focus for them because it is an automatically generated result of industrialisation. Where during the empirical research, the risk was mentioned, which was not found in theory as a motivation for constructors. This meanly has to do with the recent focus on safety on construction sites; less risk positively affects safety. For this research, both findings are considered to be valid. Besides, cost, quality, risk, and time are inseparably linked in optimising the product and are considered covered by the constructor.

Affordability is the most important aspect for clients, followed by quality and risk. For clients, the quality and risk are defined by regulations. This means that if a product is in line with the regulations, it will meet the client's quality and risk requirements. When looked at the five categories, this means that constructors and clients have the same categories covered. A reduction of time is the direct result of an industrial product and does therefore not need more optimization thus attention. It is essential to understand that this is only about the product's production time and not the time of the process. The influence on extra environmental elements is for constructors and clients, not a direct point of attention. However, this is currently defined by regulations with sustainability requirements and minimum quality restriction in the product.

For the optimization, the theoretical research describes that the product can still be improved in terms of material use, variation in the product and the reuse and circularity possibilities of the product. In the

empirical research, space planning, installations, and finishing were found as possible improvements. Digitalization is here mentioned as a resource to achieve optimisation. The barriers of the product found in this part are the additional or increasing regulation, the adaptability of the product and the lack of knowledge about the residual value. Additional and increasing regulations are here mentioned as a barrier for the innovation of the product, while as mentioned earlier, regulations are also necessary to achieve the desired quality and sustainability. This contradiction makes the consideration of regulations by public parties evident. The second recommendation will deal with the regulations and provide some guidance on how to make this consideration.

Except for additional regulation, the responsibility for all these aspects lies with the constructor. Besides, the additional regulations are not part of the product itself but only impact the product and will be covered in the second recommendation. Based on these findings, the first recommendation is:

- 1. Constructors are responsible for the innovation and digitalization of the product, which has a positive influence on the cost, quality, risk, time, and environment and is in the interest of clients, public parties, and society.*

In this recommendation, innovation and digitalization of the product are mentioned as the responsibility of the constructor. The focus on the product is essential for this recommendation. Innovation and digitalization can help to overcome the barriers that lie within the product. Due to innovation, the product will be optimized. This optimization means more efficient space planning, installations, level of finishing and variation in the product. Digitalization will optimize the impact on benefits that are already there but also help to overcome barriers. With digitalization, it will be easier to determine the residential value and the materials used, which creates possibilities for reusing and circularity in the product. Besides, with digitalization, it could be easier to automatically generate documentation for external actors such as the public parties.

In the recommendation, the constructor is the responsible actor. Because of his motivation to optimise the cost, quality, risk, and time, this will lead to innovation of the product. During the empirical research, it was found that constructors need new knowledge and experience about developing with a factory to make this step. For an optimal optimization of all five beneficial categories, public parties should steer on environmental innovation and minimum quality requirements. As described, environmental optimization is not covered by the constructors. Besides, minimum quality requirements help to set minimum requirements that align with the client's wishes, guarantee safety and comfortable living. These requirements are currently part of the building degree.

Regulations and Steering

In the theoretical research, it was found that the government has a willingness to build more houses, have the means to stimulate the market and historically proven to help a fast and economic rebuilding. However, they are currently hesitant to take a financial risk in the development of locations. In addition, regulations laid down by the government can also work against the market. The market must react to the additional regulations, which can slow down their development. The government uses these regulations as a tool to steer the market in response to the global climate crisis.

In the first part of the empirical research on the product, it was found that regulations are indeed a problem for developing a product. Changing and increasing regulations are particularly problematic in this regard. These additional regulations are on the municipal level, usually derived from the welfare levels. On a national level, the regulations to steer the market on quality and environmental aspects are increasing. The barrier of changing and additional regulations is the responsibility of the public parties. Other barriers found during the empirical research were the lack of knowledge about industrial housing and public participation. The lack of knowledge will not be covered in this recommendation but will be addressed in the fifth recommendation. The barrier in public participation will be reported as a point of attention. However, it will not be considered further because this requires changes at another level in the system of the public parties.

The process part of the empirical research also provided some opportunities and means to overcome the previously mentioned barriers. The first opportunity mentioned was the markets need for a centralized government with national guidance and regulations with a long-term vision. With national guidance and regulations, the market knows which requirements apply throughout the Netherlands for every project and will not be surprised by additional environmental and quality regulations. For product-based production, the constructor needs to know what the regulations are for the future. A long-term vision of

the public parties means that constructors know what the future will bring. A second opportunity found is the need from the market for a different way of steering. With procedures that fit a product-based production and more standardization, this can be achieved. This achievement will mean that industrial products are assessed based on standard documents. For similar products, the assessment can then be done in one go. Only location-specific requirements will then have to be assessed separately. To achieve this, better agreements between constructors and municipalities about this process must be made in advance. Digitalization from the first recommendation can help public parties to work with more standardization. The completed and approved BIM model from Figure 5.3 can automatically create standardized documentation for granting permits. The municipality will make the assessment based on this document, making it easier to respond with a standard assessment document. These recommendations are also in line with the findings from the project part of the empirical research. Here it was found that optimization of procedures and regulations are beneficial. For a building flow, this extends to automatically assessment of the same products at the same time. These findings led to the second recommendation:

- 2. Public parties should provide national guidance and regulation, using a long-term vision and standardised processes.*

This recommendation states that public parties should provide national guidance and regulations. For this guidance and regulations, they have to make a plan for the future and stick to this plan. This planning ahead is included in the recommendation with the advice to use a long-term vision. In order to optimize the processes that involve public parties, it is recommended to work towards more standardization in the documents and assessment processes.

Product-based thinking

This recommendation is focused on the role of the client. The client is (indirectly) the person for whom the product is made. However, in the last years, the number of (industrial) products on the market has highly increased. It is difficult for clients to keep track of these products and the industrial developments. During the empirical research, it became clear that there is confusion and misunderstanding about industrial housing among clients. This confusion leads to an inefficient process between the client and constructors. Overcoming this barrier will be done with the fifth recommendation.

A second major problem that was found during the empirical research is the way clients approach a project. They are used to approaching each project as a new project which creates barriers. First, in the industrial process, it is essential to involve the constructor in an early phase. This early involvement is currently not done by the clients because they are used to involve a constructor in a later phase. Traditionally, the architect was involved first and the constructor only when a design was in place. Clients still tend to approach each project as they are used to and thus not involve the constructor early enough. Besides, this new way of working requires handing overwork to the constructors, but clients are still hesitant to do this. In their project-based way of working, they are used to give a plan of requirements to the constructor. However, in the industrial process, this list of requirements does not fit the industrial product. On the financial side of industrial housing, clients are not aware of the financial benefits of the product. To overcome this barrier clients, must learn how to work with industrial products instead of using a project-based approach.

In the project part of the empirical research, these findings were underlined. Besides the early cooperation between constructor and clients, it is found that also municipalities and housing corporations should work together in an early phase. In addition, it is recommended that clients also steer the market towards industrialized products to stimulate innovation. To overcome these barriers with findings, the third recommendation is:

- 3. Clients need to take on a new role where they start thinking in terms of the product rather than the project.*

This recommendation is relatively straightforward, but it will benefit the process if the client learns how to work with an industrial product. This product-based thinking will be advantageous in the collaborations with other actors and the work of the client.

The only not addressed barrier concerning the client that was found during the empirical research is the complexity of the market due to fragmentation and the lack of insight into the product. If the client got used to working with industrial products, the fragmentation of the market is no longer a problem for the

client. The client will only contact the constructor of the product of his choice at the front end. It is the task of constructors to make their product transparent (see recommendation 2).

Contribution of the building flow

This recommendation is about the use of a building flow. The third part of the empirical research focuses on using a building flow to stimulate industrial housing. The findings are based on Eindhoven's urban area and participants involved in this building flow. In this part, only strengths or opportunities were found. This might be because the findings are based on interviewees that are involved in this project. Besides, there are yet no houses realised, which makes it challenging to look at the barriers.

In these findings, the buildings flow is a mean with the goal to have a more optimised process of producing industrial housing. In the project part of the empirical research, it was found that the confidence in the product among actors has grown. This trust had increased in the process of setting up the construction flow. In addition, during this process, cooperation and trust were created between the involved parties. It is essential to invest in an extensive preliminary process to achieve this. This extensive preliminary process includes changing in small steps and making choices about the division of roles.

For constructors, the process of a building flow has the benefit of certainty about the demand in the upcoming years. During the theoretical research, it was found that this certainty is a barrier for them to make investments such as building a factory. In the empirical research, it became clear that this certainty for investments also influences innovation. With certainty in demand, constructors have the certainty to make investments in the innovation of their product. However, not all constructors were convinced that they needed a building flow for continuity in their demand. These findings led to the following recommendation.

- 4. A building flow creates cooperation and trust in the product among clients and public parties, which accelerates innovation, but is not crucial for constructors.*

The cooperation and trust between actors ensure that the step towards the use of industrial products is made. The second part of the recommendation focuses on the interest of the different actors where a building flow would help clients and public parties but is not crucial for constructors.

During the empirical research, the benefits of an open procedure with a competitive dialogue were also found. These findings are not translated into the recommendation because they apply specifically to this case. However, they are given as beneficial aspects to make a well-considered choice. The use of an open procedure with a competitive dialogue had the advantage of being transparent towards the market. The constructors that are involved are willing to share their knowledge. This knowledge sharing created a growing support for industrial housing on the side of clients and municipalities. Besides, this approach creates the possibility to talk about concession to achieve more standardization. The competitive dialogue leaves space for clients to sit around the table with constructors. Clients have their list of requirements, and the constructor has a product with limitations. When they have the possibility to sit around the table, the constructor can explain these limitations to the client. This additional explanation can lead to concessions on the client's site, which allows the constructor to build his industrialized product. This means that with cooperation and concession, a more industrialized product can be achieved.

Another finding mentioned to optimize the building flow is a more streamlined building, production, and procedure process. With cooperation between clients and municipalities on a regional level, alignment can be reached. This alignment leads to more continuity in the process.

Incentive through knowledge for change

This recommendation is focused on changes in the way of working by knowledge. It was already stated in the problem definition that the lack of understanding is a significant problem. The theoretical findings explain that there is a need for change. This change is within the organisational structure, culture of the organisation, and the need to adopt a new way of working. These findings are acknowledged in the empirical research. The need for cultural change is here described as a mean with the goal to overcome resistance and hesitation. To do this, organisations must stimulate and enthuse their people with new ideas. Besides, the idea that they become redundant need to be overcome.

In the empirical research, it was found that ambiguities about the industrial product or process often led to delaying and unnecessary consequences. These consequences were found within the organisation

of constructors, clients, and public parties. They all need a better understanding of industrial housing throughout the organisation.

In the project part of the empirical research and as explained in the previous recommendation, cooperation and trust were reached in the building flow. The findings of a transparent process and knowledge sharing are in this building flow used to create trust and cooperation. These findings are translated to a recommendation with as a result cultural and organisational change:

5. *Transparent exchange of knowledge about industrialised products and processes leads to trust and cooperation between parties, which in turn creates internal motivation for cultural and organisational change.*

This recommendation states that there must be a transparent exchange of knowledge between parties. That this transparent exchange of knowledge leads to trust and cooperation. In addition, trust and cooperation create motivation for cultural and organisational change. This change is needed for multiple other parts of the process. Changes within organisations are difficult to reach but form the basis for understanding and support from the organisation.

6.3 Validation

The methodology chapter of this research described that an expert panel was held to validate and discuss the recommendations. During the expert panel, the five recommendations (chapter 6.2) were presented in the form of a proposition. Professionals were first asked to vote in favour, against or neutral if they do not know or are partially in favour or against. After the voting, there was time for a discussion, and every participant got the opportunity to react. However, if the conversation strayed, participants repeated themselves, or if enough has been discussed because of time, it was interrupted. With every proposition, three sub-questions were shown to stimulate participants in the discussion. These questions were: 'Do you agree with these recommendations as a professional', 'Do you think the recommendation will lead to success' and 'Are there preconditions for the success of this recommendation'. The original propositions were presented in Dutch and can be found in appendix VI. The combined findings with votes of each proposition and arguments of the discussion can be found in appendix VII.

Propositions

Product innovation

"Constructors are responsible for the innovation and digitalization of the product, which has a positive influence on the cost, quality, risk, time, and environment and is in the interest of clients, public parties and the society".

For this proposition, the votes were mixed. Participants D1 and D2 voted in favour, participant D4 and D5 neutral and D3 against the proposition. The proposition has three elements: who is responsible for developing the product, the impact of development, and whose interest is the development. The discussion was mainly focused on the responsible actor and the role of development. The development of the industrial housing product is the focus of this proposition. However, during the discussion, it became clear that participants inclined to involve the process.

1. All participants agreed on the responsible role of constructors for innovation in digitalization but implied on responsibilities of other actors to stimulate this. Participant D1 explains that constructors are responsible for developing and the contract side of these new products; other actors play a role in the process and are just as important. For digitalization, he explains that at the front, it is a collaboration. Constructors must investigate the process and the role of digitalization for all actors. When it comes to digitalization in the product, the constructor is responsible.
2. In addition to the previous aspect, knowledge and governmental institutions facilitate innovative programs to support innovation in the product (participant D5). This group takes, therefore, also takes responsibility for the innovation and digitalization of the product.
3. Participant D2 mentioned a point of attention in the innovation of the product. Constructors must be careful not to develop a technically fantastic product that does not suit the resident. Constructors must keep listening to the customers and at the same time show the market what they can and have to offer.

4. Another aspect mentioned for the development of the product is the cooperation between constructors. Participant D4 explains that housing corporations have found each other. They see that they have the same goal, which stimulates cooperation. Constructors are still competitors. It would help if they found a way to share expertise about their product development. In addition to this, participant D5 suggests that they could share a factory and produce together in this factory. The participated constructors are not yet convinced of this cooperation. Participant D3 also does not think they can produce together in a factory because they are not that far yet. If they would produce together in a factory, they have to work with the same machinery, which is currently not realistic. Lastly, competition also ensures better quality (participant D5).
5. On the process side, to optimise the product, participants consider the match between supply and demand to be essential. Participant D2 explains that they are working on a match between supply and demand. Participant D4 adds to this that constructors currently take the risk, but eventually, it must match. This match between supply and demand is a cooperation between the different actors.
6. In addition to the previous aspect, participants mentioned that the division of roles must become clearer. Interviewee D3 explains that as a sector, they are not yet at the point where we can fully implement industrialisation because the switch just started. Currently, many responsibilities lie with the constructor to tackle innovation, organise cost and quality. However, it must become clearer what everyone wants and how that will be organised. Therefore, a more precise division of task is needed.

Regulations and Steering

“Public parties should provide national guidance and regulation, using a long-term vision and standardising processes”.

All participants voted in favour of this proposition that is focused on the role of the public parties. During the discussion, participants have mainly focused on national guidance and a long-term vision. Locations and ground positions was another subject that was resaid several times during the discussion. The role of local parties, on the other hand, was hardly criticised, perhaps because the proposition was emphatically focused on the national scale. Standardising of processes was not mentioned by the participants. This might need some further explanation in implementation.

1. All participants, mainly the participants who work on the constructor side, are very firm about the long-term vision. In the last ten years, the regulations were continually changing with new requirements that had to be implemented in one to two years (Participants D2). Constructors no longer want surprises; it must be possible to anticipate on requirements that will apply in the upcoming ten years (Participant D1). This anticipation means that constructors can already go beyond the current requirements for the future. Therefore, they only need to know in advance what will happen, and they need a manual for the next ten years (participant D2).
2. In addition to the previous aspect, it is essential for constructors that guidance and regulation are national. By setting targets that transcend national boundaries, constructors can capitalise on this (interviewer D1). This national steering also means that constructors can work the same way across the country.
3. Another aspect discussed by the participants is the current guidance and regulations that should stimulate the market in different ways. Participant D5 mentioned the landlord levy, sustainable requirements, and nitrogen requirements. Currently, the public parties have the urge to stack requirements on top of each other to steer the market, but there are choices to be made (participant D2). There must be a plan with requirements to guide with prioritisation and which the market can work with. In addition to this, public parties only consider products that are 100% compliant, but some products are 95% compliant; these should be included (participant D5). With 100% complaint is meant that the product meets all the norms. However, some products do almost meet the norm, but also have enormous other advantages. For example, a product that meets 95% of the nitrogen norm is built two times cheaper. Currently, the public parties do not dare to include these products without consideration, even though they may be a better fit bottom line.
4. To help steer the market, money has been made available by the government. During the discussion participant D5 made clear that this is currently two milliards for four years to boost the housing production. This period of four years can also be found in the politic. However, the long-term vision of the proposition is added to overcome this four-year cycle. Participant D5 added to this

that money must also be made available structurally from a financial point of view. This money is needed to cover the shortage for the development of housing. This shortage has arisen and will increase due to additional requirements from public parties. Besides, the development of infrastructure is needed to create more locations for the development of housing. Clients will not cover these costs, so this money must be used to fill the shortages even after the current four years where money has been made available now. In addition, this long-term investment gives more certainty to the market. They have the certainty that public parties will support and help for the long term with housing development.

5. As mentioned, another aspect of this proposition is the ground positions. Participants on the construction side explained their concerns about available construction sites. Participant D5 reacted on this that there are enough construction sites, but there is a context to work with. These plans that must be placed in a context require much time. In addition to this, he explains that new locations require a lot of extra money to create a context, think of infrastructure. There are thus enough locations, but there is extra time needed if they are in an urban area. While if the locations are outside the urban area, there must be extra money available. This raises the question from the constructor side if national guidance on ground positions could be the solution. This national guidance must provide more certainty about available ground positions, which is currently a reason why constructors are reluctant to industrialise.
6. The final aspect discussed during this proposition is that different branch associations and the public parties should get around the table and start talking (participant D4). Participant D1 criticised this aspect because he is questioning if it will work because there are many interests at the table.

Product-based thinking

“The client must take on a new role, moving from project-based thinking to product-based thinking”.

For this proposition, all participants voted in favour except participant D2 who voted neutral to give an opposing view. All participants agreed that unique projects with their own requirements should disappear. The downsides of product-based thinking were clear. The discussion was mostly about who would take responsibility, what clients could do in their new role, and how others could help them.

1. During the discussion, it became clear that participants have a different perspective on where we are now and how far product-based thinking goes. Participant D2 indicated that clients have already made a considerable step forward. They involve the constructor in an early phase and are buying products instead of developing their own products. However, participant D3 responded that it is still a project-based way of thinking because, even though they buy a product, a new builder is contacted in every project. There is no long-term cooperation between the constructor and the client.
2. In addition to the previous aspect, participant D4 indicates that they have worked hard to clarify the urgency of industrial housing. The directors are now on board, but employees still need to be convinced. Their role is to create a successful project disappears, making it challenging to get them on board. Therefore, participant D2 suggested that clients need to find their challenge in the product somewhere else, for example, in quality or costs. In addition, clients need to accept the limits of a product because the industrial product has advantages of quality, time and costs (Participant D2). By means of example locations, Participant D5 hopes to convince others so that we start believing the product.
3. A comment on the proposition came from participant D2 on the meaning of a product. The difference between products and a house is that a house is real estate. Real estate means that it is bounded to the ground and therefore never completely the same as a product. For real estate, the location needs to be addressed. This means that one uniform product cannot answer the question. In the discussion, it became clear that this product requires a different invitation from the client to the contractor. Participant D4 reacted on this that the new invitation is coming, but this must be done by employees, which makes it difficult (see the previous aspect)
4. On the changing role of the client, the following comment was made: ‘To help clients in their new role, the market should make it easier for them to work with the product’ (interviewee D2). Make it a clear and transparent product, where the client knows what is possible and how it works.
5. The final aspect of the discussion was about responsibility. The urge that something must be done is there, but everyone points at each other and hides themselves away (Participant D1).

Participant D5 pointed here that clients address that they want to make the step and have the means. However, the urgency to act is not high enough; therefore they do not take responsibility.

Contribution of the building flow

“A building flow creates cooperation and trust in the product among clients and public parties, which accelerates innovation, but is not crucial for constructors”.

For this proposition, the votes were mixed. Participant D1 voted in favour, participants D2 and D5 neutral and D3 and D4 against the proposition. The proposition has two elements: cooperation and trust among clients and public parties and not being crucial for constructors. During the discussion, it became clear that the votes against and neutral were not in favour votes due to the second part of the proposition about the role of the constructor.

1. All participants agreed that a building flow creates cooperation and trust in the product among clients and public parties. Participant D1 explains from experience in the urban area of Eindhoven that during the presentations of the products, public parties and clients became enthusiastic. A crucial condition here is to begin the conversation, show what the product is (Participant D1).
2. In addition to the previous aspect, the innovation due to the building flow was also approved by the participants. There is a learning curve with innovation, and learning points are taken to the next project (Participant D5).
3. As a positive aspect of a building flow, participants mention the bundling of demand. Bundling and standardising the demand helps create agreements and reduces the time for alignment (Participant D3). Besides, it is crucial to make investments for innovation and a factory (Participant D1).
4. In contradiction with the previous aspect participant D1, mentioned two downsides of bundling the demand. By bundling the demand, the same requirements are applicable for each house in the building flow, while each constructor distinguishes itself. This means that the client asks for a product to the whole market, while it might be better to ask the constructor with a product that fits a specific location. The second downside is that each client of the building flow must stick to these requirements that are laid down for the whole building flow. Clients must define requirements to which they commit and then stick to.
5. Reacted to the proposition, participant D1 also questioned if a building flow is needed for constructors in the long term. The factory must be continuously running with continuous demand. It could be questioned if this is a bundled demand. Participant D4 argued that clients could take the responsibility the create this continuous demand for 15 years by making agreements with each other.
6. Finally, participant D3, without choosing a side in the previous discussion, stated that the most important part of a building flow is that it creates movement. For clients and constructors, it is important to force these movements because otherwise, nothing will happen.

Incentive through knowledge for change

“Transparent exchange of knowledge about industrialised products and processes leads to trust and cooperation between parties, which in turn creates internal motivation for cultural and organisational change”.

For this proposition, all participants voted in favour except participant D1 who voted neutral. During the other propositions, multiple elements of this proposition already came up. The proposition has the eventual goal for internal motivation for cultural and organisational change, with a mean to improve trust and cooperation between parties through transparent knowledge exchange. The discussion was mainly focused on the knowledge exchange and how to achieve this, with competition as a downside.

1. All participants agreed that knowledge exchange leads to trust and cooperation in favour of a cultural and organisational change. The momentum to make this step is there, and with knowledge sharing, more acceptance is created. Participant D1 adds to this that it does not make the process easier, but it makes it more likely to succeed afterwards because it creates a mutual understanding.
2. In the previous aspect, transparency is not included because participant D1 reacted to this part of the proposition. Transparency is important, but the competitive position between constructors must be considered. Currently, even in a transparent process, the constructor decides precisely what to show, even in the Urban area of Eindhoven, where the process was experienced as

transparent. On the other hand, participant D1 mentions that they may not have to be afraid of competition, as the products are very diverse and not easy to copy.

3. As a reaction to the discussion about transparency, participant D3 mentioned that it is crucial to learn from each other. We are used to this closed attitude; however, we will learn much faster from each other in an open process. The only condition he gives is that the market must be healthier. Currently, the market does everything for the lowest price. That should no longer be the primary approach for a healthy market. Participant D5 agrees and adds that market parties should get a fair price. Clients must stop selecting only based on the lowest price. They should make a consideration that also includes the long-term performance of a product. This means the consideration of quality and the future viability of a product.
4. Participants indicated that it is hard to find each other in this knowledge sharing, especially in an informal conversation. Participant D5 explains that they used to have this informal conversation with a small group of actors. In this small informal setting, they found each other. However, due to the success, multiple actors wanted to join, which eventually brought it down, because again, there were too many interests around the table.

07.

CONCLUSION

7. Conclusion

This chapter gives the final conclusion of this research by answering the main question:

What adaptations are needed to scale up the Dutch production of industrial housing?

The adaptations that answer this main question are based on the recommendations formulated in the synthesis (Chapter Synthesis6). These recommendations are further adapted and broadened based on the findings received during the expert panel. There is a recommendation for each part of the empirical research (product, process, and project) and each main actor (constructor, client, and public parties). Some recommendation involves multiple parts of the research or multiple actors. In addition to each recommendation, a list of conditions is given.

Product innovation

Although this research is focused on optimising the process, it was found that innovation in the product can help optimize the process during the research. Constructors must take the lead in this development but must use the support from clients, public parties, and the social environment. The first recommendation therefore is:

1. *Constructors should take the lead in the innovation and digitalization of the product; the rest of the parties should steer to develop a product that meets their needs.*

The final recommendation states that constructors are in the lead for the development of the product. This development includes innovations and digitalization of the product, which positively impacts cost, quality risk, time, and environmental aspects. This development is also in the interest of clients, public parties, and society. However, the other actors must be involved in developing the product to ensure that the product meets their interest. This steering by other actors was added to the recommendation as a result of the validation.

Conditions

- *Constructors should get in-house knowledge and experience about producing in a factory.*

In the recommendation, it is stated that constructors should innovate and digitise. For innovation and digitalization, the role of producing in a factory will become crucial. Constructors currently miss knowledge about developing with a factory since they are not used to work with a factory. This condition refers to this by indicating that constructors must acquire this knowledge.

- *Constructors should keep communicating with the market, listen to customers, and show them what they have to offer.*

In the recommendation, it is stated that constructors should take the lead. The risk is here that constructors will lead these developments on their own. Constructors, therefore, must be aware of developing a product that meets the needs of the market. In addition, they should show the market the possibilities they have to offer. This allows the market to indicate to constructors which developments are in line with their interests.

- *Public parties should steer on environmental innovation and minimum quality requirements.*

Constructors are less focused on environmental innovation. In addition, clients are comfortable with the environmental and minimum quality requirements of the public parties. With constructors in the lead, this condition ensures environmental innovation, minimum quality and thus the client's confidence in the product.

- *Public parties should help constructors with the facilitation of innovative programmes.*

The recommendation is focused on the constructors and involves other parties by indicating that they have to steer the production. This condition provides a way to help the steering the product, besides innovative programmes can ensure even more independent innovation. For example, these programmes create new cooperation between actors and increase the sharing of knowledge between parties.

Regulations and steering

This recommendation is focused on the public parties and the system of regulations and steering in the

Netherlands. There is a need for a central government and a different way of steering. These findings led to the second recommendation:

2. *Public parties should work with a long-term vision, standardization in the processes and national guidance and regulations.*

This final recommendation is focused on public parties on different scale levels. On a national and municipal level, public parties must provide a long-term vision and learn to work with standardization in the processes. With a long-term vision, the market can anticipate regulations that apply in the future. Standardization needs to be adapted in documents and assessment processes. The standardization will make every process comparable and thus easier and faster for employees.

Conditions

- *The government must give notice of new regulations whereby four-year policy is transcended.*

This condition is added to clarify that the long-term vision must also transcend the four-year policy by introducing new regulations. It also indicates that the government must communicate these regulations to the market in advance.

- *The government should make a guiding plan with prioritising guidance.*

Currently, the government is trying to steer in several directions at once, think of quality, shortages, and sustainability. With a guiding plan, the market is informed about in which way they must go.

- *The government should provide structural money to help see the market.*

Structural money will provide certainty to the market for structural public support. Besides, it covers the shortages for the development of housing that clients will not cover.

- *Public parties should together standardize the documents that are used in the processes with digitalization (developed by constructors, recommendation 1)*

Constructors can provide standard documentation to the public parties due to digitalization. Through cooperation, public parties can adopt these documents and develop their assessment documents and protocols. By cooperation between all public parties, these documents and process can also be standardized.

- *Municipalities should consider products that are not 100% compliant.*

Some products almost meet every norm and have enormous other advantages. When municipalities take these products into considerations, they may have a better product at the bottom line.

- *Municipalities should not exclude industrial products with the welfare levels.*

Small changes in the design due to the welfare levels are an enormous problem for industrial products. Welfare levels are important for the quality of our living environment, but they should not unnecessarily exclude industrial products.

Product-based thinking

This recommendation is focused on the client and how he approaches a project. He must learn to work with industrial product. This goal led to the following recommendation:

3. *Clients need to take on a new role where they start thinking in terms of the product and about projects from an overarching perspective.*

It is recommended that the client takes a new role; this means that the client's work partially changes. They are no longer the designer of the project but must find success in quality and costs. To strengthen this new role, they must adopt a product-based way of thinking instead of a project-based way of thinking. When the client has adopted a product-based way of working within a project, he must develop a new way of thinking about the project from an overarching perspective. This means corporation between constructors and clients within different projects.

Conditions

- *Clients need to understand the industrial product (covered in the 5th recommendation)*

If clients must work with the industrial product, they must understand the product and its benefits. For this condition, it is crucial to involve all employees to create support and commitment.

- *Clients need to have more insight into the available products (covered in the 1st recommendation)*

If clients must work with the industrial product, they must know what the products specifications are. They need to get more insight into the available products on the market, including prices and possibilities of the product. This information should be provided by the constructors and be easily accessible for clients.

- *Clients should consider long-term cooperation with constructors.*

With long-term cooperation with constructors, an overarching perspective on projects can be reached. This means that agreements can be made about the use of products in different projects, ensuring that the advantages of the industrial product are utilised even more effectively. Besides, the phasing can be coordinated from an overarching perspective, which leads to greater efficiency. This optimization will benefit the cost and quality of the client.

- *Clients need to get their employees on board with a new challenge in the product.*

As explained, clients must take on a new role where they are no longer the designer of the project. All employees must be involved in this change towards a new role. This can be done to get them motivated with a new challenge in the product. They should be stimulated to find a challenge in quality, price, or other beneficial elements of a project.

- *Clients should approach the product like real estate, where more than one uniform product is needed.*

The difference between industrial products and other products is that this is real estate and is therefore location-specific. One uniform product can therefore not be the solution for every project. Clients need to address this to the constructor when they start working with an industrial product. There is enough variation possible within an industrial product, but this should be discussed with the constructor in advance.

Contribution of a building flow

This recommendation is focused on the use of a building flow. It explains the benefits of using a building flow but does not say that a building flow is essential to use. In addition, when a building flow is used, it provides conditions to let it succeed. This led to the following recommendation:

4. *A building flow creates cooperation and trust in the product among clients and public parties, and this accelerates innovation with a learning curve for industrialisation.*

The most important element of a building flow is that it creates cooperation and trust among clients and public parties. Cooperation and trust are currently experienced as a barrier in the progress of industrialisation because clients and public parties do not yet stand behind the product. The second part of the recommendation is focused on the result of a building flow for the total development and follow-up projects. This part is included because, for the validation, it was suggested that a building flow is not crucial for constructors. However, they indicated that they could benefit from the acceleration of industrialisation.

Conditions

- *Between clients and constructors, there should be a possibility to talk about concessions in the product.*

The possibility to talk about concessions creates space for constructors to explain the limitations of their product. As a result, clients may allow concessions to make it possible to use an industrial product. Clients then have the benefits of an industrial product, which would be otherwise not possible to use.

- *Constructors should be willing to talk about their product and show what their product can do.*

To create trust in the product, constructors must explain their product and its benefits. However, constructors are used to working in a competitive market but simultaneously see that sharing this information does not cause them to lose their position. They must thus overcome this standard way of working and start the conversation.

- *Clients must define requirements for the product that fit each project; this could include multiple types of products in the invitation.*

In a building flow, clients currently ask the market for one product with the same specification. However, it might be that a variant of the product fits better in a particular place. At the same time, most constructors can make variations within their product that do without compromising on any of the benefits. Therefore, it would be better if clients define requirements that fit the whole building flow, including product variations.

- *Clients must stick to the product they have defined after the agreement.*

In a building flow, multiple actors define their requirements for the product together. Constructors fear that clients will come back to the requirements that have been laid down in advance. This means that clients come up with additional requirements for the design later in the process, which can mean that the industrial product is no longer suitable. Clients must therefore define requirements to which they commit and then stick.

Incentives through knowledge for change

The last recommendation involves all actors of the process and their way of working. Cultural and organisational barriers are found throughout the whole process and are difficult to change. It will take an extensive process, but the momentum is there. This has led to the fifth recommendation:

5. *Transparent exchange of knowledge about industrialised products and processes leads to trust and cooperation between parties, which in turn creates internal motivation for cultural and organisational change.*

This recommendation has not been changed as a result of the validation. The recommendation states that a transparent exchange of knowledge leads to trust and cooperation, which is the driving force for cultural and organisational change. Transparency in the process is discussed during the validation as a part of this recommendation. The discussion had to do with competition in the market, making transparency difficult, mainly between constructors. However, constructors also indicate that more transparency is possible without sharing competitively sensitive information. Besides, we must learn from each other and overcome the closed attitude that the market is used to. Therefore, transparency is included as part of this recommendation.

Conditions

- *All employees involved in industrialisation must be included in this change.*

Those who pioneered industrialisation are already behind the idea, but this does not yet apply to everyone within companies. It is important to obtain understanding and support from every employee, whereby the idea to become redundant need to be overcome to overcome the barrier of resistance and hesitation. This shift requires a cultural and organisational change in which everyone must be involved.

- *Clients must stop selecting products only based on the lowest price.*

We must learn from each other in a transparent process, wherefore a healthy market is crucial. Our current market is not healthy because clients only select constructors based on the lowest price, while they should consider the long-term performance of a product.

- *Constructors must learn to become more open in the process towards clients and each other.*

As mentioned above, transparency is a crucial element to trust and cooperation. Constructors are afraid of competition and not used to work in an open process. This condition is added to overcome this barrier and lead to more cooperation and trust between constructors and clients. Besides, it will create an environment where constructors can learn from each other.

- *Actors should find a place for the informal conversation; this should be small groups of different actors.*

The informal conversation is experienced as an accessible and helpful way of sharing knowledge. With small groups of different actors, the goal of an informal conversation is most likely to be successful. Different actors will create enough interest around the table to learn from each other. Whereby small groups must ensure that there are not too many interests around the table.

08.

DISCUSSION

8. Discussion

This chapter discusses the research process and the output of this research. This research is not the endpoint towards industrialisation; further steps need to be taken, requiring additional research. In this chapter, first, the relevance of this research is examined, followed by the limitations of this research. Finally, a recommendation for further research will be provided based on the limitations and conclusions given in the previous chapter.

8.1 Relevance

This research is socially relevant because it answers a socially relevant problem with as context metropolitan areas and their current position in globalisation. The urge for sufficient and affordable housing in a world where we cannot ignore globalisation is undebatable. Over the past year, the problem has been frequently mentioned in the news, newspapers, articles, webinars, podcasts, etc. It is brought to our attention, but still, not much has changed. The prices of houses are still rising, and the availability of houses is limited. If you are looking for an affordable house, there is nothing you can do to change this situation. Home seekers stand helplessly on the sidelines, looking for a roof over their heads.

Fortunately, there is some movement visible. The awareness among politicians and municipalities to deal with this situation has grown. In addition, constructors are developing industrial products to answer this demand, and clients are increasingly willing to invest in these products. Industrial housing could provide a solution to reduce the pressure on the market. Besides, industrial housing is a product that provides possibilities in sustainability. This research gives recommendation to the market to scale up the production of industrial housing and therefore provides a solution to make affordable living more accessible.

This research is also scientifically relevant because it aims to close the gap of knowledge between research on the development of (industrial) housing and the practice. Several studies have been conducted on the development of housing. Since the start of mass customization and prefabrication, worldwide research has been done on these developments. In recent years, industrial housing has become a widely used term in the Netherlands, but we are still in the development of industrial housing. The scope of industrial housing is therefore not clearly defined in available research. Some studies give insights about how they interpreted industrial housing, but these studies can contradict each other. This research aims to provide a clear definition of industrial housing and give insight into the process.

8.2 Limitations

Research limitations

Theoretical limitations

There is minimal scientific research available on the topic of industrial housing. The scope of industrial housing is now defined within this research. If there had been more literature on industrial housing, it would be easier to set the boundaries for this research. This unclear scope was also apparent in conversations with actors in the field. During the interviews, time was made available to get on the same page or know what the interviewees understanding of industrialisation was. However, during knowledge sharing in the interviews, it was sometimes difficult to ascertain whether shared knowledge fell within the scope of this research. In contradiction to the limited scientific research available, much has been published during the conduction of this research. The subject has received much attention recently, resulting in many new publications from the government and knowledge institutions. These publications have been taken note of during this research, but not all research data has been processed in this research.

Case Selection

Within this research, a case study was used to investigate a building flow in the urban area of Eindhoven. This case was selected because it is the building flow that is currently the furthest along of all the building flows. However, the decision to take this and only this building flow has its limitations. The first limitation of this case project is that no houses are realized within this building flow. Agreements between client, public parties and constructors have been made, but it cannot be said that this building flow will be successful. In addition, this is the only building flow that is investigated in this research. The decision for

a one-case case study is mainly made because of time limitations. The choice has been made to include the point of view of all parties involved in this building flow instead of interview one actor from multiple parties. To overcome this limitation, actors interviewed that were not part of this building flow were also questioned about their experience or view on working with a building flow. Besides, some of the findings are not translated to the recommendation because they were too case-specific.

Broader context

During the research, there are barriers found that are in the hands of the public parties. These barriers mainly apply to the general findings of the process part of this research. These findings relate to problems that can be found in a broader context. This broader context means that these barriers are also encountered for other housing projects, thus not industrial housing. These barriers include, among other things, the steps that a building process legally must go through, the participation of citizens in this process and how welfare is applied to building projects. The recommendations include some advice to help overcome these barriers that are of impact on industrial housing. However, some drastic changes to these barriers could bring even more significant benefits. The recommendations given in this research are not drastic changes but changes that have a greater chance of succeeding. Drastic recommendations are not provided because they have a lower chance of succeeding, and if they are adopted, it will take time. This research, therefore, provides recommendations that work without completely overturning basic procedures within the public system.

Market limitations

Uncertainty in the future

During the research, it became clear that uncertainty in the future is an essential barrier for constructors that need to invest. This uncertainty is about the number of households is not overcome in this research. This research assumes that the shortages will still increase in the coming years. It is not sure that we need all those houses in the long term, it can lead to overcapacity. However, if reusing and circularity are included in the industrial products, this will be resolved.

The complexity of the market

During the empirical research, it was found that the construction market is very complex. This complexity has to do with the fragmentation of the market and the system to build houses. In the empirical research, it was found that citizens do not understand the system, and fragmentation makes it difficult for clients. During the writing of this research, this complexity to gain insight into the market as a researcher also became apparent. During the research, it became clear that each actor has much knowledge about his part of the process. In addition, they all had a clear position due to the background in which they operate. For information gained through actors in the field, it can be questioned whether they have a good view of the entire process. This thought applies to the interviews, expert panel, and other conversations with actors in the field.

Competition on the market

Constructors active in the industrial housing market experience great competition, as found during the expert panel. One of the recommendations states that it would be good if constructors could be more transparent about their product. For this research, several constructors were asked to contribute. Among the constructors, a lot of willingness was shown to participate in this research. However, some parties explained that due to competition, they could not transparently share all their knowledge. Besides, parties that have contributed have decided by themselves what they share and whatnot. This competition on the market could have led to limitations for information gained in this research.

Change through time

In the research, it is explained that cultural and organizational change is needed. In the conclusion, recommendations are given to create this change. However, it is not considered in this research that organizational and cultural change needs time. There is a lot of scientific research available on cultural change and organizational change, and an entire study could be devoted to this change to promote industrial housing. However, that would be significantly out of line with the main focus of this research. For this research, it must be acknowledged that organizational and cultural change needs time and that it cannot be achieved by just following these recommendations. The recommendations must therefore be seen as a first step in the right direction.

8.3 Further research recommendations

As mentioned in the examination on the relevance, this research tries to provide the scope of industrial housing. However, this research is limited by the literature that was available beforehand. At the same time, the subject is now prevalent, which leads to multiple new publications. We are in the middle of the development, and this can also be seen in the case study used for this research. The case that is chosen for this research is also still unfinished and has no realised results yet. Therefore, the first recommendation for further research is that the developments in the coming years should be monitored with additional studies. In these studies, the scope of industrial housing will have to be continuously reviewed with the developments on the market. In addition, it will be possible to reflect on multiple and completed building flows in the future. This research can look at the advantages or disadvantages of a building flow and compare the different ways in which a building flow has been applied. Differences can be searched for in which actor is involved in which phase, which agreements are made, the way of tendering, and the project's success.

The third limitation explains that this research is limited by its context. Procedures, regulations, and policies in the hand of the public parties are complex and challenging to change. The second recommendation for further research would be to devote further research to the public system. Firstly, this study should investigate how recommendation from this study can be implemented. Therefore, it must be studied how national guidance and regulations can be given substance and how a long-term vision can be implemented. In addition, a study can be conducted into how standardisation can be implemented. It should be investigated what a standard document and procedure should look like and how it will be supported nationally. Besides exploring possibilities with recommendations of this study, research in procedures, regulations, and policies can also be further explored. At present, a building project is still very much delayed by the procedures of the public system. Further research should look at where further optimisation is possible; this includes objection periods, public participation, and the role of welfare levels.

Alongside recommendations for further research to optimise the process, this study also touches points for further research into the product. This study clarifies that digitalisation is essential, but we are not at the point where we can implement this. Therefore, further research will have to be done into how different actors use or would like to use a digital model, subsequently investigating how these digital models work together in a linear process. In addition, follow-up research can be done on the application of industrial housing. In this research, several points of discussion about what industrial housing should be or how it should be used were given. Further research can be done in the way it is produced; think of the production method and the elements of an industrial house. In addition, it can be studied in which way product can be applied, the target group, the location, and the stacking of products.

Finally, it would be interesting to research what is needed for a cultural change in a conservative sector. One essential aspect to accelerating industrialisation is the support, knowledge sharing and trust of the entire sector; this requires organisational and cultural change. Although there is already research on this subject, it is interesting to examine this in connection with the conservative construction sector. Therefore, a study on gaining support with the possible role of modern tools can be performed. With the current technology, we can use virtual reality, 3D-modelling and online platforms to show what industrialisation means for our built environment.

09.

REFLECTION

9. Reflection

This chapter reflects on the research process and the experience of conducting this research. It, therefore, first explains the selection of this topic and will then reflect on the method used for this research. During the research, many elements of the research have changed. These changes are mainly due to findings during the investigation that steered the research into a new direction. This part describes how the research was conducted, how it has changed and how it may be perceived. Finally, a personal experience of conducting this research will be provided.

9.1 Topic selection

This research is part of the track Management in the Built Environment, which is positioned in the master program Architecture, Urbanism, and buildings sciences at the TU Delft. This track contains three research sections: Real Estate Management (REM), Design and Construction Management (DCM) and Urban Development Management (UDM). This graduation research falls in the domain of Real Estate Management and has a connection with the topics of housing systems and housing management. Housing systems aim to unravel the functioning of the housing market with the goal to deliver answers for current problems in the housing market. The topic of housing management focuses on organizational strategies to manage and (re) develop the housing stock with the goal to increase the socioeconomic and environmental sustainability of housing provision.

With this research, I wanted to answer a socially relevant problem with metropolitan areas and their current position in globalisation as a context. In my opinion, the housing market is the most socially relevant part of our built environment and, at the same time, more complex than most other construction industries. However, our housing market is currently under tremendous pressure with problems in the construction sector and growing population; the shortages will only increase further.

This research started with the idea that prefab is already a more affordable way of living and a solution for multiple households, but unfortunately with a bad image. When I heard about the concept of industrial housing, I was directly interested. Not only because this transition can solve the shortages in the housing market, but it also has common ground with sustainable and circular development.

This research aimed to identify the adaptations in the process that are needed to scale up the production. First, a better understanding of the housing market in relation to industrial housing was obtained. After which, a solution was sought for the problems on the housing market concerning industrial housing. Implementation of the adaptations needed to scale up leads to the increased socioeconomic and environmental sustainability of housing provision. In that way, this research will contribute to the topics of housing systems and housing management.

9.2 Methodology

The goal of the literature study was to get familiar with the subject of industrial housing. In this literature study, the scope of industrial housing had to be defined. Besides, it had to provide a clear view of the process and the actors that were involved. Theories on the development of housing were used to get an understanding of the historical developments around housing. These theories were focused on the Netherlands but also across the borders. From the start of industrial housing, there is not much literature to investigate. Most of the literature about industrial housing comes from the Netherlands and do not give a clear definition of the scope. Therefore, it was challenging to gain a structured overview of different terminologies used in this field. To obtain a clear understanding of the process and the different actors involved, literature on traditional housing systems was used to make a comparison. The information on the actors and the process were translated to an illustration of the traditional and industrial process.

During the empirical research, the findings of the theoretical framework became more comprehensible. The illustration of the industrial production process became the underlayer for the empirical research to get on the same line with interviewees.

On beforehand, the empirical study was divided into two parts of qualitative research, case studies and general practice. The idea of the case study was that there are already multiple concepts of industrial housing on the market, but there is still a minor increase in production. With the use of case studies and the theoretical framework, the idea was that different concepts would become comparable with

each other. The cases are tested on their product (the house) with associated performance and the production process. This comparison could then give new insights about how specific concepts perform in relation to what is found in theory. However, during the first conversations before the interviews, it became clear that it is difficult to compare these products. Besides, it was already done in another study, 'De ideale conceptuele woning' (van Empel, 2020) and it could be questioned if it would answer the main research question. The main research question is focused on the process and actors that are involved in this process. By comparing the different products, the research would focus on the product. During the P2, it was also commented that the focus should be more on the process than on the product.

The second part of the empirical was meant to focus on the general practice. This section should provide an analysis of the barriers and opportunities experienced by the actors involved in the process. The actors involved in the process mean constructors of the different concepts and social housing associations, public parties, and residents. With analyzing barriers and opportunities in the process, this part of the empirical research was more focused on the process. After the exploratory conversations of the empirical research, it was decided to change the case study method. The information about products was integrated into the interviews on the general practice. This meant that the interviews on general practice were divided into parts, the product and the process. In the product part, constructors were questioned about their own product while other actors were questioned about their experiences with different products.

During one of the first interviews, the building flow in the urban area of Eindhoven was brought up. After some sort of investigation and conversations with involved actors about this building flow, it was decided to include a building flow as a case in the research. Building flows are the way used to get industrial housing up and running. With this case, a building flow was integrated into the research without stating that it is needed for industrial housing. The opportunities and barriers of this building flow were gained through extra interviewees. For these interviews, actors involved in the building flow in Eindhoven were interviewed. This information was collected in the third part of the interview on the project. As a result, the empirical research output was divided into three parts: product, process, and project data.

In the synthesis, the results of the research will be analyzed and implemented. It was decided beforehand that all findings from the empirical research were compared to the theoretical framework with triangulation. The comparison of data in triangulation is still performed, but now on the three different parts of the output and the theoretical framework. The synthesis still answers the main question of the research with recommendations, but in addition, an expert panel was held to validate the recommendations. The expert panel findings were integrated into the formerly established recommendation, leading to the final conclusion of this research.

9.3 Reflection on the research process

This paragraph reflects on the experience of conducting this research. This paragraph is therefore written from a personal perspective.

Towards the P2

At the beginning of the academic year in 2020, I started to set up my graduation research. To select a topic, I looked at social relevant problems that we currently face in our built environment. In a previous master course, Housing Policy, Management, and sustainability, I conducted a research in housing systems and governance. During this research, my interest in the housing shortage and the challenge and possibilities that can be faced in the future was aroused. As a result, I came up with three topics that I might want to investigate for my thesis research: the functioning of prefabricated housing, the impact of the crisis on the housing stock and the development of sustainable housing for the future. I found it particularly interesting that prefabricated housing might be the solution for the housing shortages, but there is a very negative stigma around it. In the first conversation with my first mentor, my interest in this subject grew because it could also provide a sustainable solution for the future. Besides, multiple large constructors were already developing new products at the time. The concept of industrial housing was completely unknown to me when I chose this direction.

In the week that followed, I started to investigate this far-reaching development in the use of prefab and the products on the market. This made me familiar with the term industrialisation and immediately made me aware of the confusion about the term. The following period was mainly devoted to gaining as much knowledge on the subject as possible. I acquired this knowledge through webinars, factory tours

and the connection to the transition project of the Bouwcampus. Besides, there was much publicity about industrialisation in the media to be inspired by. It was interesting to get in touch with the practice, and it became clear how wildly this topic was being discussed. At the same time, I started to set up my research methodology. It seemed apparent to compare different housing concepts. However, the problem was mainly in the process and the actors that are involved. Working toward my P2, I experienced that it was challenging to give substance to the research in the process. For my literature research, I started with the historical background on industrialisation. It was interesting to better understand the origin of mass customization and the causes of the current situation. More problematic was the definition of the scope. I experienced that when I explained my topic to others, no one was yet familiar with the term industrialisation. This lack of clarity was also visible in literature where different sources contradicted each other, and a clear definition was lacking. Therefore, I decided to give a clear definition of industrialisation for this research.

Nevertheless, I noticed that this definition had been adjusted in the process of my research. Finally, in the run-up to my P2, I started looking for an internship to link my research to. I chose to look for a constructor who sees potential in industrialised products. I got in touch with the business development department of Heijmans woningbouw, who offered me a place to do my internship. The choice for a large construction company was primarily made from a personal interest, to look at a large construction company. Ultimately, an additional benefit has been that I was able to gain much more insight into the building process.

Towards the P4

The main feedback on the P2 was that the focus was still too much on different industrial products rather than the process. With the methodology that I proposed, it would be hard to identify barriers and opportunities in the process. In addition, a clear framework of barriers and opportunities for the theory was missing. In the week that followed, I made a clear established theoretical framework. Based on this theoretical framework, I made a protocol for my interviews. By linking the interviews directly to the theoretical framework, all actors and opportunities and barriers were involved. With that, there was an immediate shift to focusing on the process. With the knowledge of the interview protocol, I entered discussions with employees from different perspectives during my internship. At this point, I realised that the complexity of the building process and my personal need for an overview of the process. I made this process drawing with knowledge from the broadening interviews. This overview became a nice handhold for me and became useful during interviews and conversations about the process. When I had enough information and was sure that the protocol would provide the desired information, I started the in-depth interviews. This is the phase of the research I enjoyed the most. It was interesting to speak with experienced people from different perspectives whom all feel the urge of the shortages on the housing market. In addition, I had the opportunity to visit offices, factory halls and construction sites, which is a pleasant excursion, especially in times of covid-19. At the same time, I noticed that it is challenging to come up with ground-breaking results. During interviews, you hear people repeating each other, which was why I thought: when will I hear something new. At these moments, it was good to reflect that when I started this research, I did not even know what industrial housing was, let alone how it works.

During the elaboration of my results, the report became more structured, and the story became complete. For the validation of my results, I performed an expert panel. For this expert panel, I looked very broad for participants. What I also noticed during my interviews is that people are very busy and making appointments at short notice is particularly difficult. However, it was nice to see how much interest there was for my research from people who could not participate. The expert panel itself was also an exciting experience. During my research, I participated in multiple webinars where there was always high interest in my opinion on the topic of industrialisation. In these discussions, mostly someone from a knowledge institution was leading the discussion. During the expert panel, I was in the role to lead the discussion, whereby the participants all wanted to share their opinion. Besides the experience of performing an expert panel, it has been very valuable for my research.

Finally, in this phase, I approached Heijmans about whether they wanted to collaborate on an informative animation about industrialisation. As a result, I am involved in the marketing side of Heijmans. Here I worked with an external party from Heijmans on an animation to explain the industrial process. The making of this animation was an interesting course of action where you think carefully about providing a simple explanation in a few minutes.

Towards the P5

The main feedback on the P4 was that it needed more sharpening towards conclusions and recommendations for the future. In the last weeks, I attempted to bring the outcomes of this research to a higher level. In the methodology, I added an explanation of the decision making in the synthesis. In addition, an explanation of the conclusions had been added. Accordingly, a great deal of effort has gone into the discussion and reflection. In the discussion, more substance is given to explain the limitations of this research and a recommendation for further research is added. With writing this part, it became clear to me that in this section, you can describe the things that you have encountered along the way but have not yet been able to give a place in the research. With elaborating on these parts, they have been given a place in this research.

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APPENDICES

Appendices

I. Appendix A - Theoretical PESTLE analysis

Adapted elements of the PESTLE

- (P) Political: The role of the government and the impact government policies concerning industrial housing
- (E) Economic: Factors that impact the economy, which has a direct impact on the production process. This includes the costs for companies to be part of this production process
- (S) Social: The impact of the social environment on industrial housing. This includes a growing population, individuality and ageing, but also the change in type of housing and housing trends
- (T) Technological: Innovation that could affect the market and thus the production process of industrial housing
- (I) Institutional: The influence and power of institutions and their cultural and organisational habits
- (E) Environmental: The influence on the surrounding environment and impact on ecological aspects, this includes the current concerns about climate change.

(P) Political: The role of the government and the impact government policies concerning industrial housing

Pro

- Active land policy in the Netherlands (background)
- Willingness to build more houses (background)
- Stimulate the market (services, advice, subsidies and granting permits) (actors)

Con

- Regulations in the built environment (spatial plan, zoning plan, building decree) (actors)
- Uncertainty available ground (current position)
- Hesitation from the government, less financial risks (background)

(E) Economic: Factors that impact the economy, which has a direct impact on the production process. This includes the costs for companies to be part of this production process

Pro

- Product costs reduced (benefits)
- Costs production process reduced (benefits)
- More affordable housing (benefits)

Con

- High one-time start investment (current position)
- Uncertainty in the future, structural demand for housing can change (current position)
- Uncertainty in a continuous demand (current position)

(S) Social: The impact of the social environment on industrial housing. This includes a growing population, individuality and ageing, but also the change in type of housing and housing trends

Pro

- Fast and economic rebuilding of the housing stock (historical)

- Sustainable benefits of industrial housing are popular
- Personal wishes can be integrated more and more easily

Con

- Resistance against uniformity and flexibility (historical)
- Quality above quantity (historical)
- Confusion about the concept of industrial housing (problem statement)

(T) Technological: Innovation that could affect the market and thus the production process of industrial housing

Pro

- Continuously optimization of the production process (benefits)

Con

- Uncertainty with suppliers by standardised components (current position)
- Challenges in the product (current position)

(I) Institutional: The influence and power of institutions and their cultural and organisational habits

Pro

- Expertise in the construction field (actors)

Con

- Stubbornness of the building industry, hardly accessible for renewing (historical)
- Demand for cooperation between actors (problem statement)
- Demand for change in the organisation (current position)

(E) Environmental: The influence on the surrounding environment and impact on ecological aspects, this includes the current concerns about climate change.

Pro

- Offsite Production process is not affected by external factors (benefits)
- Product is better for the environment, more sustainable, circular product including a material passport (benefits)
- Use of more sustainable materials / reduced waste (benefits)
- Production process is better for the environment (benefits)

Con

- The image of concrete in the Netherlands (practise)
- There is no whole lifetime experience yet, reuse

II. Appendix B - Information sheet interviews

Informatie overzicht interview

Onderzoek	MSc thesis: Scale up the production, The realisation of industrial housing
Instituut	Delft University of Technology
Onderzoeker	Tessa Meij

Met dit document wil ik u informeren over uw deelname aan dit onderzoek. Mocht u na het lezen van deze informatie nog vragen hebben, dan hoor ik het graag.

Deelnemen aan het onderzoek

Het doel van dit interview is om bij te dragen aan mijn afstudeeronderzoek. Dit onderzoek is onderdeel van mijn afstudeerproject van de Master Management in the Built Environment aan de TU Delft. Dit onderzoek analyseert het thema van industrieel bouwen en de bijbehorende mogelijkheden en belemmeringen in het realisatie proces. Met dit onderzoek wordt inzicht gekregen in welke actoren betrokken zijn in het proces en hoe dit proces kan worden verbeterd. Het doel van dit onderzoek is om een systematisch overzicht te geven van aanpassingen die nodig zijn in de praktijk om mogelijkheden te benutten en belemmeringen te verhelpen.

In dit gesprek zullen we de volgende onderwerpen behandelen:

0: Uw professionele achtergrond

1: Uw visie op industrieel bouwen en huidige producten

3: Uw ervaring met huidige kansen en belemmeringen in het proces

3: Toekomstige scenario's

Het interview zal worden opgenomen, hierbij zijn er geen goede of foute antwoorden, het is uw visie die telt. U hoeft geen antwoord te geven op alle vragen en kunt me altijd onderbreken. De totale tijd van het interview is ongeveer 60 minuten.

Gebruik van data gedurende het onderzoek

Nadat het interview is afgenomen zal de audio opnamen worden uitgeschreven. Informatie over in welk productieproces u betrokken bent zal expliciet blijven omdat dit essentiële variabelen zijn voor het onderzoek. Alle andere persoonlijke informatie en projectgegevens zullen worden geanonimiseerd, u zult niet traceerbaar zijn. Persoonlijke informatie, zoals uw naam, zal niet worden gedeeld buiten het onderzoeksteam. Het onderzoeksteam bestaat uit mijzelf (Tessa Meij), mentoren vanuit de TU Delft (Peter Boelhouwer en Gerard van Bortel) en de afgevaardigde van de examencommissie van de TU Delft (Steffen Nijhuis).

Toekomstig gebruik en hergebruik van data door anderen

Na het afronden en inleveren van mijn onderzoek zal deze worden gepubliceerd op het online onderzoeksplatform van de TU Delft (<https://repository.tudelft.nl>). Het doel hiervan is dat data beschikbaar blijft voor verdere kennisontwikkeling, innovatie en onderzoek. Gevoelige data dat onderdeel is van dit onderzoek zal niet worden gepubliceerd, maar blijft binnen het onderzoeksteam. Dit betekent dat bij het delen van het onderzoek gevoelige gegevens worden verborgen of weggelaten en dat in geen enkel geval gegevens kunnen worden herleid tot een specifiek persoon. Neem contact op via T.I.Meij@student.tudelft.nl als u hierover vragen of opmerkingen heeft.

Bedankt voor uw medewerking en bijdrage aan dit onderzoek!

III. Appendix C - Interview protocol

Algemene informatie

Datum: [Datum]

Geïnterviewde: [Naam]

Bedrijf: [Bedrijf]

Functie: [Functie]

Interviewer: Tessa Meij

Functie: Graduation Student 'Management in the Built Environment', TU Delft

Introductie

Bedankt voor het deelnemen aan mijn onderzoek over de industrialisatie van de woningbouw. Dit onderzoek is onderdeel van mijn afstudeerproject van de Master Management in the Built Environment aan de TU Delft. Dit onderzoek analyseert het thema van industrieel bouwen en de bijbehorende mogelijkheden en belemmeringen in het realisatie proces. Met dit onderzoek wordt inzicht gekregen in welke actoren betrokken zijn in het proces en hoe dit proces kan worden verbeterd. Het doel van dit onderzoek is om een systematisch overzicht te geven van aanpassingen die nodig zijn in de praktijk om mogelijkheden te benutten en belemmeringen te verhelpen.

Met dit interview wil ik meer inzicht krijgen in uw visie op industrieel bouwen in het algemeen, kansen en belemmeringen die u tegenkomt in het proces en aanpassingen die het proces zouden helpen. Er zijn hierbij geen goede of foute antwoorden, het is uw visie die telt. U hoeft geen antwoord te geven op alle vragen en kunt me altijd onderbreken. De totale tijd van het interview is ongeveer 60 minuten.

Tijdens het gesprek zijn de volgende documenten verkregen of ingezien:

Tijdens of na het gesprek zijn de volgende opmerkingen gemaakt:

0. Professionele achtergrond

- Wat is uw functie binnen de organisatie waar je werkt?
- Wat is uw rol in de industrialisatie van de woningbouw?

1. Visie op industrieel bouwen en product

- Hoe zou u industrieel bouwen omschrijven? (*Doel: kijken naar onduidelijkheid rond om begrip industrieel bouwen*)
- Wat zijn voor uw organisatie belangrijke redenen om het productieproces van [product] te industrialiseren?

> *kosten, betaalbaarheid, snel, duurzaam, innovatie, hergebruik*

- Heeft [product] bereikt waarvoor deze was/is ontwikkeld?
- Waar zitten in [product] nog door ontwikkel mogelijkheden?

> *uitdagingen in product (materiaal/digitaliseren)*

2. Ervaring van het Proces

In dit stuk kijken we naar het productieproces van een industriële woning. Dit doen we de aan de hand van het schema (zie bijlage). Toelichting op schema: Aan de linkerkant staan de verschillende actoren die betrokken zijn in het proces van industrieel bouwen. Het werkt eigenlijk zo dat de opdrachtgever met zijn vraagstuk naar de bouwer gaat. De bouwer heeft in het geval van industrieel bouwen een continu proces, dit is aangegeven met het grijze vak. Dit houdt in dat de fabriek continu draait en dus al standaard componenten heeft voordat de opdrachtgever bij de bouwer aan klopt.

Aan de hand van dit schema kijken we eerst binnen de organisatie en betrokken partijen, dan de invloed van de overheid en tot slot de invloed van de samenleving.

- Kunt u zich vinden in de elementen van die schema? Zijn er nog toevoegingen/aanpassingen binnen het productieproces waar u bij bent betrokken?

De opdrachtgever

- Wat ziet u binnen de samenwerking met de opdrachtgever als factoren die industrialisatie stimuleren?
- Wat ziet u binnen de samenwerking met de opdrachtgever als factoren die industrialisatie moeizaam maken?

> Onzekerheid continuïteit

- Heeft u opmerkingen of aanpassen binnen de samenwerking met de opdrachtgever ter bevordering van de industrialisatie?

Bouwer

- Wat ziet u binnen uw organisatie als factoren die industrialisatie stimuleren?

> ervaring

- Wat ziet u binnen de organisatie als factoren die industrialisatie moeizaam maken?

> financieel, organisatorisch

- Heeft u opmerkingen of aanpassen binnen de organisatie ter bevordering van de industrialisatie?

Leveranciers

- Wat ziet u binnen de samenwerking met leveranciers als factoren die industrialisatie stimuleren?

> samenwerking

- Wat ziet u binnen de samenwerking met leveranciers als factoren die industrialisatie moeizaam maken?

> onzekerheid, standaardisatie

- Heeft u opmerkingen of aanpassen binnen de samenwerking met leveranciers ter bevordering van de industrialisatie?

De ontwerper

- Wat ziet u binnen de samenwerking met de ontwerper als factoren die industrialisatie stimuleren?

> Grotere variatie

- Wat ziet u binnen de samenwerking met de ontwerper als factoren die industrialisatie moeizaam maken?

> Ontwerper is beperkt

- Heeft u opmerkingen of aanpassen binnen de samenwerking met de ontwerpers ter bevordering van de industrialisatie?

De overheid

- Wat ziet u binnen de samenwerking met de overheid als factoren die industrialisatie stimuleren?

> Actief Nederland grondbeleid, bereidheid, stimulatie (services, advies, subsidies, permits)

- Wat ziet u binnen de samenwerking met de overheid als factoren die industrialisatie moeizaam maken?

> Regelgeving (ruimtelijk plan, bestemmingsplan), onzekerheid grond, aarzeling

- Heeft u opmerkingen of aanpassen binnen de samenwerking met de gemeente ter bevordering van de industrialisatie?

De sociale omgeving

- Wat ziet u binnen de sociale omgeving als factoren die industrialisatie stimuleren?

> Persoonlijk aanpasbaar

- Wat ziet u binnen de sociale omgeving als factoren die industrialisatie moeizaam maken?

> onzekerheid in vraag, verzet, hogere kwaliteit vereist, imago van beton

- Heeft u opmerkingen of aanpassen binnen de samenwerking met leveranciers ter bevordering van de industrialisatie?

3. Toekomstige scenario's

- Hoe zien jullie herbruikbaarheid in jullie product/ de industrialisatie?

> Circulariteit, hergebruik van materiaal

- Hoe denkt u over het samenvoegen van verschillende actoren in het productieproces?

> *Bijv. Opdrachtgever is ook de bouwer of er is geen leverancier van materiaal meer nodig*

4. Inbreng/ Reflectie

- Zijn er nog onderwerpen die ik niet besproken heb, maar die wel van belang zijn?
- Of Wilt u nog iets toevoegen aan dit gesprek?

IV. Appendix D - Synthesis SWOT

Strengths/ Opportunities		
Category	Responsible Actor	Aspect
P	Public party	- Active land policy in the Netherlands
P	Public party	- The government has the willingness to build more houses.
P	Public party	- Public parties can stimulate the market (services, advice, subsidies and granting permits)
S	All	- Historical proven that fast and economic rebuilding is possible.
S	Social env.	- Sustainable benefits of industrial housing are popular.
S	Social env.	- Personal wishes can be integrated more and more easily.
T	Constructor	- The quality of the product improves; this includes a better control and consistency of the quality because products are factory-made.
T	Constructor	- The production process time is reduced because the construction time is shorter, and the process time is optimised.
Ec	Constructor	- The optimised production process is more efficient in time and resources; this leads to a cost reduction of the product and the process.
E	Constructor	- Risk in the process is reduced due to the optimisation of the process and the fact that the product is constructed in a factory.
Ev	Constructor	- The process and the product are better for the environment; this includes sustainability, reduction of waste, circularity and the use of a material passport
Weaknesses/ Threats		
Category	Responsible Actor	Aspect
P	Public party	- Regulations in the built environment
P	Public party	- Hesitation from the government to take financial risk.
Ec	Social env.	- Historical resistance against uniformity and flexibility.
S	Social env.	- Historical preference for quality over quantity
S	All	- Confusion about the concept of industrial housing.
I	Client/Const.	- The stubbornness of the building industry, hardly accessible for renewing
I	All	- Lack of cooperation between actors on the market
E	Constructor	- High one-time start investment <ul style="list-style-type: none"> • Hesitation among constructors • Only a small number of companies have the capital to make this step.
S	Constructor	- Uncertainty in future number of households
E	Constructor	- Uncertainty in a continuous market demand
P	All	- Uncertainty available ground
T	Constructor	- Uncertainty with suppliers, be supplier-dependent due to standardised components.
	All	- Need for change. <ul style="list-style-type: none"> • Cultural change • Organisational change
S		
I		
T	Constructor	- Challenges in the product <ul style="list-style-type: none"> • Use of new materials. • Variation in the product • Reuse and circularity
T	Constructor	- No experience in whole lifetime of a product, the reuse of material

Product Framework

Strengths/ Opportunities		
<i>Category</i>	<i>Responsible Actor</i>	<i>Aspect</i>
Ec	Constructor	- Municipalities and housing corporations focus on the affordability of the product.
T/Ec	Constructor	- Constructors focus on using a factory to produce to optimize cost, quality and risk.
Ev/T	Constructor	- Quality and environmental aspects are for the clients defined by regulations.
Ev	Constructor	- (new) material use can be optimized.
T	Constructor	- Space planning could be more efficient.
T	Constructor	- Installations and the level of finishing can be optimized.
T	Constructor	- Digitalization can optimize the product.
Weaknesses/ Threats		
<i>Category</i>	<i>Responsible Actor</i>	<i>Aspect</i>
Ev/T	Constructor	- Optimization of environmental aspects and a faster production is less important for constructors.
P	Public party	- Within the municipality responsibilities thus interest to optimize the product are divided
P	Public party	- Additional or increasing requirement hinder innovation of the product (welfare levels).
T	Constructor	
Ec	Constructors	- The adaptability of the product in use is a problem. - Lack of knowledge about the residual value

Process Framework

Strengths/ Opportunities		
<i>Category</i>	<i>Responsible Actor</i>	<i>Aspect</i>
P	Public party	<ul style="list-style-type: none"> - Need for a centralized government with national guidance and regulations with a long-term vision. <ul style="list-style-type: none"> • Help with creating more ground positions. • Additional regulations are a risk for a product-based production.
P	Public party	<ul style="list-style-type: none"> - Need for a different way of steering. <ul style="list-style-type: none"> • Change in procedures, more standardization. • Better agreements in advance
T	Constructor	<ul style="list-style-type: none"> - Crucial consideration to build a factory. <ul style="list-style-type: none"> • Need for new knowledge and experience about a factory.
T S/I	Supp/Const. All	<ul style="list-style-type: none"> - Suppliers working together with constructors leads to innovation. - Cultural change is needed. <ul style="list-style-type: none"> • Stimulation and enthuse them for new ideas to overcome resistance. • Hesitation to become redundant need to be overcome.
Weaknesses/ Threats		
<i>Category</i>	<i>Responsible Actor</i>	<i>Aspect</i>
P	Constructor	<ul style="list-style-type: none"> - Not enough ground positions are a problem for every actor in the field. <ul style="list-style-type: none"> • Risk in the continuity of the process
P	Public party	<ul style="list-style-type: none"> - Public participation in every level of a construction project
S	Client	<ul style="list-style-type: none"> - Confusion and misunderstandings about industrial housing <ul style="list-style-type: none"> • Lack of efficiency between client and constructors
I	Client	<ul style="list-style-type: none"> - Project-based thinking instead of product-based thinking <ul style="list-style-type: none"> • Contractor not always early involved. • Not aware of financial benefits of industrial product • Hesitation to hand over work • Plan of requirements do not fit in the industrial process.
S	Client	<ul style="list-style-type: none"> - Fragmentation of the market makes in complex.
Ec	Constructor	<ul style="list-style-type: none"> - Crucial consideration to build a factory. <ul style="list-style-type: none"> • Need for enough capital.
T	Constructor	<ul style="list-style-type: none"> - More transparently in shelling the product to the client is needed.
S	Constructor	<ul style="list-style-type: none"> - Internal capacity and understanding of industrial product.
S	Public party	<ul style="list-style-type: none"> - Lack of knowledge about industrial housing
I	Suppliers	<ul style="list-style-type: none"> - Public utilities companies are unpredictable and not keeping up with time.
S	All	<ul style="list-style-type: none"> - The system to build houses is complex. <ul style="list-style-type: none"> • Citizens do not understand the system. • Difficult procedures create hold-ups in the process.

Project Framework

Strengths/ Opportunities		
<i>Category</i>	<i>Responsible Actor</i>	<i>Aspect</i>
Ec	All Constructor Client/ PP All All Public party Client Client/ PP	<ul style="list-style-type: none"> - Confidence in the industrial product - Certainty about the demand in the upcoming years <ul style="list-style-type: none"> • Certainty to invest in innovation for industrialization. - Early cooperation between municipality and housing corporations <ul style="list-style-type: none"> • Actors all stood behind the defined product. • Actors realized they have common goals and no longer saw each other as competitors. - Open procedure with the competitive dialogue. <ul style="list-style-type: none"> • Transparency to constructors on the market • Exchange of knowledge by constructors • Growing support for industrial housing on side of housing corporations and municipalities • Possibility to talk about concessions to realise more standardization. - Create cooperation and trust. <ul style="list-style-type: none"> • Changing in small steps • Extensive preliminary process • Make choices about the division of roles. - Optimize procedures and regulations. <ul style="list-style-type: none"> • Purchase obligation to stimulate innovation. • Automated product assessment for same products • Standardized location specific permits - Focus on industrialized products. <ul style="list-style-type: none"> • Stimulate the market to innovate. - Streamline building, production, and procedure processes. <ul style="list-style-type: none"> • Cooperation between corporations and municipalities on regional level
Weaknesses/ Threats		
<i>Category</i>	<i>Responsible Actor</i>	<i>Aspect</i>

V. Appendix E - Expert panel information sheet

Informatie overzicht expert panel

Onderzoek	MSc thesis: Scale up the production, The realisation of industrial housing
Instituut	Delft University of Technology
Onderzoeker	Tessa Meij
Datum	10 mei 2021
Tijd	10:00-12:00

Met dit document wil ik u informeren over mijn onderzoek en de verwerking van de data. Mocht u na het lezen van deze informatie nog vragen hebben, dan hoor ik het graag.

Deelnemen aan het onderzoek

Dit onderzoek is onderdeel van mijn afstudeerproject van de Master Management in the Built Environment aan de TU Delft. Dit onderzoek analyseert het thema van industrieel bouwen en de bijbehorende mogelijkheden en belemmeringen in het realisatie proces. Met dit onderzoek wordt inzicht gekregen in welke actoren betrokken zijn in het proces en hoe dit proces kan worden verbeterd. Het doel van dit onderzoek is om een systematisch overzicht te geven van aanpassingen die nodig zijn in de praktijk om mogelijkheden te benutten en belemmeringen te verhelpen.

Inmiddels zijn vanuit een literatuur en empirisch onderzoek aanbevelingen voor de markt opgesteld. Om deze aanbevelingen te controleren en laatste tegenspraken uit de weg te gaan ben ik opzoek naar een expert panel ter validatie van mijn onderzoek. Tijdens het panel zullen verschillende aanbevelingen worden voorgelegd in de vorm van een stelling. Naast de validatie van deze aanbevelingen is er ruimte voor discussie. Nieuwe inzichten die tijdens dit panel worden opgedaan worden meegenomen in mijn eindconclusie.

Het gesprek zal worden opgenomen, hierbij zijn er geen goede of foute antwoorden, het is uw visie die telt. U hoeft geen antwoord te geven op alle vragen en kunt me altijd onderbreken.

Gebruik van data gedurende het onderzoek

Na afloop van het panel zal de audio worden gebruikt om nieuwe inzichten mee te nemen in mijn conclusies. Informatie over in welk productieproces u betrokken bent zal expliciet blijven omdat dit essentiële variabelen zijn voor het onderzoek. Alle andere persoonlijke informatie en projectgegevens zullen worden geanonimiseerd, u zult niet traceerbaar zijn. Persoonlijke informatie, zoals uw naam, zal niet worden gedeeld buiten het onderzoeksteam. Het onderzoeksteam bestaat uit mijzelf (Tessa Meij), mentoren vanuit de TU Delft (Peter Boelhouwer en Gerard van Bortel) en de afgevaardigde van de examencommissie van de TU Delft (Steffen Nijhuis).

Toekomstig gebruik en hergebruik van data door anderen

Na het afronden en inleveren van mijn onderzoek zal deze worden gepubliceerd op het online onderzoeksplatform van de TU Delft (<https://repository.tudelft.nl>). Het doel hiervan is dat data beschikbaar blijft voor verdere kennisontwikkeling, innovatie en onderzoek. Gevoelige data dat onderdeel is van dit onderzoek zal niet worden gepubliceerd, maar blijft binnen het onderzoeksteam. Dit betekent dat bij het delen van het onderzoek gevoelige gegevens worden verborgen of weggelaten en dat in geen enkel geval gegevens kunnen worden herleid tot een specifiek persoon. Neem contact op via T.I.Meij@student.tudelft.nl als u hierover vragen of opmerkingen heeft.

Bedankt voor uw medewerking en bijdrage aan dit onderzoek!

Expert Panel | **SCALE UP THE PROCESS**

The realization of industrial housing

Beste deelnemer,

Allereerst hartelijk dank voor uw deelname aan mijn panel. Dit panel heeft voor mij als doel het valideren van de aanbevelingen die ik heb geformuleerd op basis van mijn literatuur en empirische onderzoek. Met valideren bedoel ik: Kunt u zich als professional in deze aanbevelingen vinden? Denk u dat de aanbevelingen leiden tot succes? Zijn er nog voorwaarden verbonden aan het slagen van deze aanbevelingen? Tijdens het panel zullen 5 verschillende aanbevelingen worden voorgelegd in de vorm van een stelling. Naast de validatie van deze aanbevelingen is er ruimte voor discussie. Nieuwe inzichten die tijdens dit panel worden opgedaan worden meegenomen in mijn eindconclusie. Daarnaast hoop ik ook dat het voor u als aanwezige een interessant moment is om van elkaar te leren, ervaring op te doen en alvast inzicht te krijgen in mijn resultaten.

Het gesprek zal worden opgenomen, hierbij zijn er geen goede of foute antwoorden, het is uw visie de telt. U hoeft geen antwoord te geven op alle vragen en kunt me altijd onderbreken. Onderstaand vindt u wat aanvullende inhoudelijke informatie wat betreft mijn onderzoek om meer inzicht te krijgen in hetgeen ik precies aan het onderzoeken ben. Deze informatie zal ik ook tijdens de introductie van het panel toelichten.

Mocht u voor het panel nog vragen hebben, stel ze gerust.

Agenda

09.55:	Inloop
10.00:	Welkom en voorstelronde
10.10:	Introductie onderzoek
10.15:	Voorleggen stellingen en discussie (+-15 min per stelling)
11.30:	Afronding, vragen en feedback

Datum:	Maandag 10 mei, 2021
Tijd:	10:00 – uiterlijk 12:00
Locatie:	Online (teams uitnodiging)

Probleemstelling

Ondanks deze voordelen en de producten die er al zijn, worden de meeste nieuwe huizen nog steeds op traditionele wijze gebouwd. Dit betekent een uitgebreid programma, een lang proces, hoge risico's en hoge bouwkosten, bovendien wordt voor elk project een nieuw plan ontwikkeld. Er zit veel potentie in geïndustrialiseerde producten, maar bouwers weten nog niet hoe ze de stap kunnen maken waarbij betrouwbare voordelen garandeert zijn.

Het eerste probleem is dat er veel verwarring bestaat over het begrip industrieel bouwen. Velen denken dat we al industrieel bouwen door het gebruik van prefab materialen. Echter is Prefab al zeker 50 jaar de standaard, en gaat industrialisatie veel verder. Het off-site produceren van losse onderdelen is niet de enige innovatie die we nodig hebben voor industriële woningbouw. Voor deze transitie spreken we over off-site productie op grote schaal op basis van een productieproces. Om dit productieproces in gang te zetten, moet en bouwers investeren in de realisatie van een fabriek. Dit betekent een hoge eenmalige investering, die daarom alleen is weggelegd voor de grotere organisaties en pas rendabel wordt vanaf een minimale productie. Deze grote investering doet bedrijven aarzelen om te investeren, zij moeten toekomst zien in de markt.

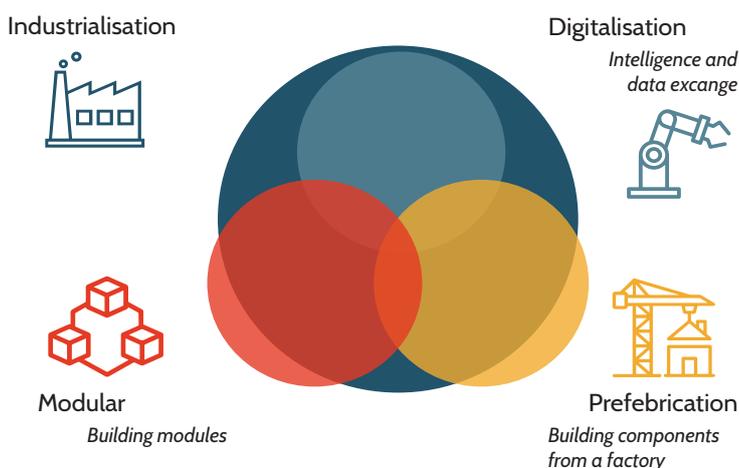
Naast de bouwers die producten ontwikkelen, zijn er vele andere actoren bij het proces betrokken, bijvoorbeeld woningbouwcoöperaties, investeerders en publieke partijen. Elke actor in het proces moet in actie komen om de transitie te maken; ze moeten elk hun eigen manier van werken aanpassen en gaan samenwerken. Een aantal bouwers hebben al een industrieel product ontwikkeld, maar zij lopen tegen het probleem dat het productieproces nog niet klaar is voor opschaling. Dit betekent een gebrek aan structurele samenwerking, er zijn momenteel verschillende belemmeringen om optimaal gebruik van het productieproces te maken.

Doel van het onderzoek

Dit onderzoek analyseert het onderwerp van industrialisatie van de woningbouw en de mogelijkheden en barrières om dit proces op te schalen. Het doel is om inzicht te krijgen in de actoren op de markt en het productieproces van industrieel bouwen, om vervolgens de aanpassingen in het proces te identificeren die nodig zijn om de productie op te schalen. Het streven is om uit deze analyse een systematisch overzicht te geven van de aanpassingen die in de praktijk nodig zijn om de kansen te benutten en de barrières te overwinnen.

Scope industrieel bouwen

De markt ziet industrieel bouwen als de industrialisatie van het product en het proces. De rol van een fabrieksmatige aanpak (herhalen, automatiseren, robotiseren, voorwaardelijke omstandigheden) en innovatie in het product (gestandaardiseerde variatie, digitalisering) zijn essentieel.



Het bovenstaand figuur illustreert het verband tussen de verschillende labels van ontwikkeling en overlap in industrialisatie. Het resultaat van de combinatie van deze ontwikkelingen leidt tot een industriële woning. Deze industriële woning wordt geproduceerd volgens een off-site fabricagemethode om modulaire, gefabriceerde en volledig gestandaardiseerde woningen te produceren. Het resultaat van dit proces is geen concept maar een product.

Voor industrieel bouwen kan worden overwogen:

- Of de fabriek een productielijn, een assemblagelijn of beide is.
- Of het product bestaat uit 2D-, 3D-modellen of een combinatie daarvan.
- Of het gaat om conceptuele woningbouw of industriële woningbouw.
- Wat de doelgroep is.
- Wat de locatie is.
- Of het om een gestapeld, ongestapeld product of beide gaat.

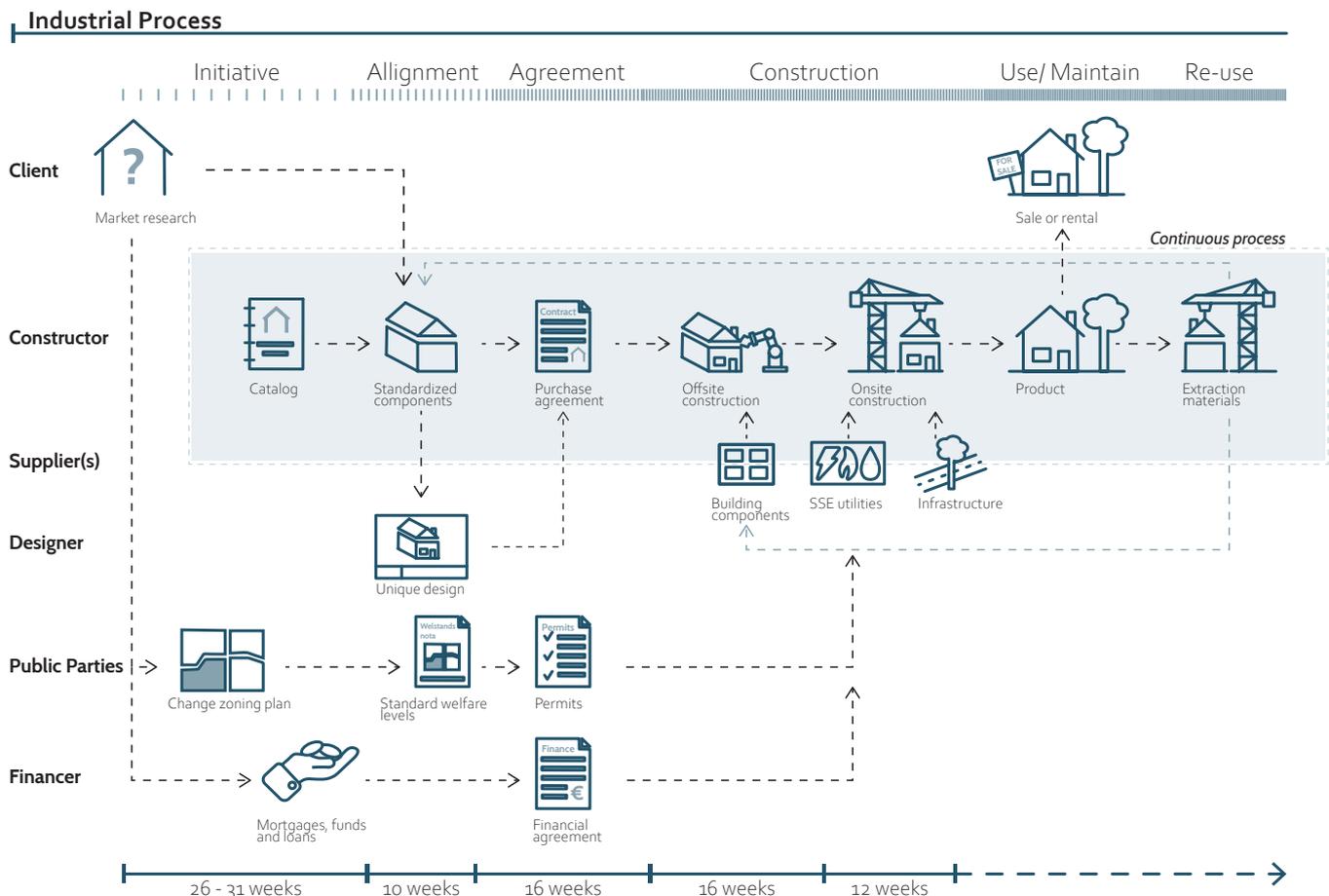
De voordelen

De voordelen van industrialisatie in het product en het proces hebben een invloed op de vijf categorieën: kwaliteit, tijd, kosten, risico en milieu.

- I. **Kwaliteit:** De kwaliteit van het product verbetert; dit omvat een betere controle en consistentie van de kwaliteit omdat de producten fabrieksmatig worden vervaardigd.
- II. **Tijd:** De tijd van het productieproces wordt verkort, omdat de bouwtijd korter is en de procestijd wordt geoptimaliseerd.
- III. **Kosten:** Het geoptimaliseerde productieproces is efficiënter in tijd en middelen; dit leidt tot een kostenverlaging van het product en het proces.
- IV. **Risico:** De risico's in het proces wordt verminderd door de optimalisatie van het proces en het feit dat het product in een fabriek wordt vervaardigd.
- V. **Milieu:** Het proces en het product zijn beter voor het milieu; dit omvat duurzaamheid, vermindering van afval, circulariteit en het gebruik van een materialenpaspoort

Het proces van industrieel bouwen

Onderstaand figuur illustreert de betrokken actoren en proces van industrieel bouwen.



STELLINGEN

1. Bouwers zijn verantwoordelijk voor innovatie en digitalisering van het product, dit heeft positieve invloed op de kosten, kwaliteit, tijd, risico's en duurzaamheid, en is in het belang van opdrachtgevers, publieke partijen en de samenleving.

2. Publieke partijen moeten zorgen voor landelijke sturing en regelgeving waarbij gebruik wordt gemaakt van een lange termijnvisie en processen worden gestandaardiseerd.

3. Opdrachtgevers moeten een nieuwe rol aannemen waarbij ze vanuit het product gaan denken in plaats van het project.

4. Een bouwstroom zorgt bij opdrachtgevers en publieke partijen voor samenwerkingen en vertrouwen in het product, dit leidt tot een versnelling om actie te ondernemen, maar is voor bouwers niet cruciaal.

5. Transparante kennisuitwisseling over geïndustrialiseerde producten en processen leidt tot vertrouwen en samenwerking tussen partijen waarbij interne motivatie ontstaat voor cultuur en organisatorische verandering.

VII. Appendix G - Expert panel findings

x#		Proposition 1
D1	✓	<ul style="list-style-type: none"> - Bouwers zijn aan ontwikkelaars en aannemerskant verantwoordelijk voor ontwikkelen van die nieuwe producten andere partijen spelen ook een rol in het proces en zijn minstens zo belangrijk om het op gang te krijgen. - Ja wij zijn verantwoordelijk voor dat digitaliseren van dat product, er zit nog wel veel meer aanvast - Digitaliseren is aan de voorkant een samenwerking. Hoe verder je in het proces kijkt, daar waar het om het product gaat is het de verantwoordelijkheid van bouwer
D2	✓	<ul style="list-style-type: none"> - Wij zijn met een zoektocht bezig om vraag en aanbod op elkaar af te stemmen. - Innovatie van de sector in triple helix - Bouwer is verantwoordelijk, is een hele grote opdracht! - Oppassen dat we geen philps worden, technische een fantastisch product ontwillen dat niet bij klant aansluit: blijf naar de klant luisteren anderzijds als je klant aan het woord laat komt er nooit een iphone. Je moet ook vanuit de maakmarkt laten zien wat je in huis hebt
D3	X	<ul style="list-style-type: none"> - Wij zijn als sector nog niet zo ver om dit volledig in te richten. We staan aan de vooravond, rol verdeling is nog niet duidelijk. Er ligt veel verantwoordelijkheid bij de bouwer om innovatie te pakken en de kosten en kwaliteit te organiseren. Daar zijn we nog niet, we moeten een duidelijkere rolverdeling krijgen. Wat wil iedereen hebben en hoe gaan we dat organiseren? - Volgens mij kunnen we nog niet in een fabriek produceren, zo ver zijn we nog niet - Opvallend dat je wil zien dat er minder concurrentie is binnen bouwers
D4	/	<ul style="list-style-type: none"> - Het zit ook aan de vraagkant. Bouwers nemen risico, maar het moet ook aansluiten. Het is een samenwerking van die partijen. - Aanbod kant is extreem toe genomen in afgelopen 2 jaar. - Betaalbaarheid mist in dit stuk - Proces van interne verandering duurt snel 7 jaar. - Bouwers zijn concurrenten van elkaar, het zou helpen als er iets gevonden wordt waardoor ze expertise kunnen delen. Woningcorporaties hebben elkaar gevonden, die zien dat ze het zelfde doel hebben
D5	/	<ul style="list-style-type: none"> -Mensen zoeken gewoon een woning - Bottem line ben ik het er mee eens. Bouwers zijn verantwoordelijk voor innovatie in het product - Ook overheid en universiteiten draaien innovatieve programma's om te ondersteunen op innovatie in product - Grootste aandacht voor betaalbaarheid - Waarom delen we geen fabriek? Bouwers samen in een fabriek produceren - Product ontwikkeling is niet los te zien van proces ontwikkeling - Concurrentie zorgt ook voor kwaliteit

Proposition 2

D1	✓	<ul style="list-style-type: none"> - Twijfel over voldoende locaties. - Geen verrassingen meer - Inspelen op huidige eisen voor over 10 jaar mogelijk maken. Eerder boven de regelgeving zitten - Bouwer is nu volgend - Is landelijke sturing op grondposities een oplossing? - Landelijk overstijgende doelen, dan kunnen marktpartijen inhaken - Branch verenigingen, gaat dit werken? Veel belangen van partijen
D2	✓	<ul style="list-style-type: none"> - Drang naar stapelen van eisen. Niet alleen publiek verantwoordelijk, maar op een gegeven moment gewoon kiezen
D3	✓	<ul style="list-style-type: none"> - Ontzettend behoefte aan lange termijn visie. Afgelopen 10 jaar veel wisselende regelgeving. Behoeft aan lange termijn visie om te investeren in innovatie. Je wilt een beeld hebben voor over 10 jaar. Nu komen eisen binnen 1 a 2 jaar. - Handleiding voor komende 10 jaar.
D4	✓	<ul style="list-style-type: none"> - Hoe komt het dat locaties als grootste obstakels wordt genoemd terwijl je zegt dat er genoeg locaties zijn aan Bas - Gesprek met verschillende branch verenigingen voeren
D5	✓	<p>die voor 95% voldoen. Deze zouden ook mee moeten worden genomen. Dit durven publieke partijen atm nog niet aan.</p> <ul style="list-style-type: none"> - Eisen om te stimuleren: Verhuurdersheffing afschaffen (geef corporaties meer armslag), groene eisen, stikstof eisen - Woningbouw impuls geld. 2 miljard over 4 jaar. -> Ga naar structureel geld - Maak een keuze! - Er zijn genoeg locaties, maar niet locaties waar niks is. Plannen vragen veel tijd - Bij nieuwe locaties ook veel geld nodig voor infra. Dit geld moet voor meerdere jaren vrijgemaakt

Proposition 3

D1	✓	<ul style="list-style-type: none"> - Wanneer pakken we gezamenlijk onze verantwoordelijkheid. Iedereen wijst naar elkaar en duikt zelf weg. De urgentie van woning te kort is echt wel duidelijk
D2	/	<ul style="list-style-type: none"> - Product is onroerend goed, daarmee wordt het nooit een 100% product. Hoe ga je inspelen op de plek, met product denken. Dat uniform product, daarmee gaan we de vraag niet beantwoorden. - Meer product dan traditionele project - Waar ik echt vanaf wil elk project uniek, elk eigen stempel en eisen - Corporaties hebben behoorlijke stap gemaakt van vanaf begin bouwer betrekken. Inkopen in plaats van ontwikkelen - Ontwikkelaar makkelijker maken om met product te werken. - Accepteren van begrenzing die product heeft, kwaliteit, tijd en geld.
D3	✓	<ul style="list-style-type: none"> - Wordt bij opdrachtgevers echt nog heel veel project matig gedacht. Geen lange termijn koppeling aan een bouwer. Elk project zoek je een nieuwe bouwer. Geen geranties voor lange termijn. De wil is er misschien, in praktijk zie je niks
D4	✓	<ul style="list-style-type: none"> - Verander process van 7 jaar zijn we aan het doorlopen. De bestuurders hebben 2 jaar geleden ja gezegd, die willen wel. Vraag is nu hoe je de medewerkers mee krijgt. Projectontwikkelaars zijn erg trots op eigen project, dat verdwijnt. Bij medewerkers! - Er zijn al bestuurders die zeggen conceptueel of industrieel als het echt niet anders kan. Zijn nog zoekende naar bouwer. Blijven het moeilijk vinden om project los te laten - Reactie op joost: Ze zijn ermee bezig - Urgentie hebben we afgelopen jaren hard aan gewerkt, bestuurders zijn aan bord. Medewerkers moeten nieuwe vraag gaan publiceren. Het komt eraan!
D5	✓	<ul style="list-style-type: none"> - Vraag bij gemeente als opdrachtgever voor andere grondhouding. - Koppelen aan menselijke maat. De buurvrouw, de .. Iedereen in directe omgeving - Iedereen wil, kunnen is geld, grond etc., moeten? De urgentie is nog niet hoog genoeg. - Er zijn locaties (voorbeeld locaties) waar we gaan beginnen. Met deze voorbeelden andere overhalen, dan gaan we erin geloven.

Proposition 4

D1	✓	<p>Tijdens presentaties van bouwers werd dit door deze partijen omarmd.</p> <ul style="list-style-type: none"> - Ga dat gesprek aan, laat zien wat het product is! - Tweede deel (voor bouwers cruciaal), het is fijn dat vraag gebundeld wordt, omdat je het over grote aantal woningen hebt. Belangrijk voor stap naar investeringen (in fabriek). Nadeel alles van de vraag wordt op een hoop gegooid, allemaal zelfde uitvraag. Terwijl markt partijen zich gaan onderscheiden, uitvraag moet meer op product - Op termijn hebben wij een bouwstroom nodig? De fabriek moet continue draaien en er moet continue vraag zijn. Maar komt dat uitgebundelde vraag?
D2	/	
D3	X	<ul style="list-style-type: none"> - We staan aan de vooravond van deze beslissingen. Ik vind het wel cruciaal, de opdrachtgevers kant moet daar in mee. Je moet deze bewegingen forseren, anders is het gedoemt te mislukken - Overheden moeten zorgen dat er gebouwd kan worden zich aan lange termijn visie/ regelgeving - Vraag bundelen en algemeniseren. Bulk afspraak met standaard stroom. Dan hoef je ook niet telkens aan tafel te gaan
D4	X	<ul style="list-style-type: none"> - Openbaar uitvragen gekozen zodat er minder discussie is intern - Tegen door voor bouwers niet cruciaal. Ik denk dat wij als corporaties en opdrachtgevers verantwoordelijkheid kunnen nemen om een continuïteit te creëren over 15 jaar. Dan kunnen bouwers een plan maken voor 15 jaar.
D5	/	<ul style="list-style-type: none"> - Je ziet inderdaad leerpunten die worden meegenomen

Proposition 5

D1	/	<ul style="list-style-type: none"> - Transparantie en kennisuitwisseling: Ja, maar we hebben een concurrentie positie. Dus 100 % eens, maar wel met het idee dat wij altijd vanuit ons eigen belang opereren. - Bijvoorbeeld Eindhoven. Proces was transparant, maar kozen wel zelf wat er werd laten zien. - Misschien moeten we er ook minder bang voor zijn - Gemiste kans dat we elkaar nu al niet weten te vinden. Maakt proces niet makkelijker, maar kans van slagen daarna wel. Creert wederzijds begrip
D2	✓	<ul style="list-style-type: none"> - Partijen zijn bijeenkomst van NEPROM over industrieel bouwen over hun schaduw heen gestapt en delen meer. - Webinars dragen bij aan de voedingsbodem, er wordt meer geaccepteerd - Het is een eerste stap, er is een momentum
D3	✓	<ul style="list-style-type: none"> - Belangrijk dat we leren van elkaars punten. Meer open leggen dan we gewend zijn. We zijn gewend dat dicht te doen, maar ik denk dat we veel sneller gaan als we van elkaar gaan leren. Voorwaarde: Gezondere markt meer specialisme. Huidige beweegrede: alles op laagste prijs, die moet eruit. Je moet normaal kunnen verdienen.
D4	✓	<ul style="list-style-type: none"> - Marktpartijen moeten een eerlijke prijs krijgen. Opdrachtgevers moeten ophouden met alleen selecteren op laagste prijs. - Partijen selecteren die bereid zijn om kennis te delen, processen te delen, mensen te delen. Dat is bij renovatie projecten nu al zichtbaar succesvol. Met goede afspraken - Uitdaging van woonagenda, waar begin je? Maar in deze agenda staan wel partijen met zelfde belang
D5	✓	<ul style="list-style-type: none"> - Gezamenlijk materiaal inkoop om kosten te drukken? - Kennis uitwisseling door vliegende brigade. Kennis om te ontwikkelen is bij corporaties en gemeente afwezig. Wij investeren in deze kennis doorgeven. - Dit bestond in de vorm van PROMA, provinciaal marktoverleg. Dat was fantastisch, we vonden elkaar informeel. Met allemaal partijen aan tafel dat is aan succes ten onder gegaan omdat iedereen er bij zat - Bij woonagenda wordt opgemerkt, we missen het informele gesprek. Dat zijn we weer aan het opstraten. Op onderling vertrouwen elkaar opzoeken.

VIII. Appendix H - Interview transcript

Note: The transcripts of this interviews are included in a separated file and only accessible for the research group. If you wish to access this information, please contact the author

Master thesis

1 july 2021

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