# Moving towards a sustainable housing construction supply chain

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bam

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By

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# Preface

The purpose of this master thesis was to explore how the Dutch housing construction chain could become more sustainable. This exploratory research was performed for the study Construction Management and Engineering (CME) at the Delft University of Technology. This research was conducted in collaboration with the construction company Royal BAM Group nv. Their expertise and network created a basis for good case study research. Knowing that the Dutch housing construction chain is slowly shifting to a sustainable future, I hope that this research contributes to accelerating this process.

# Acknowledgements

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# Executive summary

To prevent and reverse detrimental climate and biodiversity change, it is essential to motivate the housing construction supply chain to reduce the emission of carbon and nitrogen. The need to reduce the amount of emitted greenhouse gases and nitrogen oxides ($NO_x$) is even more urgent in the Dutch housing construction, where there is a severe lack of housing options on the one hand, and it is challenging for construction firms in this industry on the other hand to secure the necessary permits due to strict $NO_x$ and $CO_2$ emission laws. Currently, little research has been conducted into what hinders and motivates actors in the housing construction industry in their collaborative pursuit towards sustainable supply chain management (SSCM) in the Dutch housing construction industry. This master thesis is an exploratory study on the barriers that slow down and the drivers that facilitate the implementation of sustainability in the housing construction chain.

The goal of this study is to provide new insights for actors in the housing construction chain, the government and science. To gain these new insights, the following research question has been formulated: *How can the collaboration between actors in the Dutch housing construction industry be improved in the pursuit of sustainable supply chain management?* This research was conducted through an in-depth case study research, based on literature research and semi-structured interviews with representatives from the most influential actor types in the Dutch housing construction supply chain.

The housing construction supply chain contains a wide variety of actors with key players herein being main contractors, property developers and so-called first tier subcontractors, which refers to subcontractors that are directly contracted by the main contracting party. Main contractors interact with both property developers and first tier subcontractors, thereby playing an important central role in the chain. Additionally, property developers are highly influential in the design of the construction project. This means they make design choices specifying the materials that need to be used in the project that main contractors and (first tier) subcontractors carry out. Furthermore, first tier subcontractors are responsible for delivering the commodity or service specified in the contract between them and the main contractors. The greenhouse gas and $NO_x$ emissions that occur during the production of these goods or the delivery of services need to be taken into account when analyzing the barriers and drivers to implement sustainability in the supply chain. From a Life Cycle Assessment, it was found that the top four most emitting first tier subcontractor types were companies that provided steel, concrete, brick and construction site preparation.

Subsequently, a literature study was done to find the barriers and drivers that emerge during the implementation process of SSCM in other industries. These barriers and drivers are divided into six categories: (1) economic and financial, (2) market and networking, (3) organizational, (4) regulatory and institutional, (5) social and cultural and (6) technological. The barriers and drivers from the literature, as well as the categories were used as a starting point to conduct the interviews and analyze the obtained results from the interviews.

The barriers experienced in other industries most relevant to this research are: lack of money to invest, bad collaboration between companies, stay with traditional technology and culture, insufficient environmental competencies and lack of understanding and knowledge on SSCM among organizations in the chain. On the other hand, the drivers experienced in other industries most relevant to this research are: create a market pull, create an environmental collaboration between main contractor, subcontractor and property developer, a support system offered by the government with regulations

and effective legislation, create awareness among involved parties and create a sustainable corporate culture.

During the analysis of the interview results, an extensive amount of barriers and drivers were uncovered that actors encounter during the implementation of SSCM in the Dutch housing construction industry. The barriers experienced in the Dutch housing construction industry most relevant to this research are: institutional rules are not clear enough and multi-interpretable, the price for a sustainable product is too high to implement it, uncertainties in the market competition, it is not clear for all company employees where to acquire the right information for them to work, produce of buy sustainable products and subcontractor gets involved in the project too late, so that useful expertise can no longer be used. Additionally, the drivers experienced in the Dutch housing construction industry most relevant to this research are: get rid of partners that do not want to work sustainable, the main contractor communicates with subcontractors and property developers and shares their information, educate staff to use sustainable methods, share financial burdens together and a long term vision of the government.

When comparing the barrier categories between actor types in the construction chain, several observations were made. For all actors, the economic and financial category was found to be the most important, meaning that the barriers within this category where mentioned the most compared to other categories. Furthermore, it is remarkable that subcontractors and property developers experience many barriers in the market and networking category, whereas main contractors experience this to a lesser extent. Conversely, main contractors experience more barriers in the regulatory and institutional category. This indicates that the focus of main contractors lies elsewhere when identifying barriers than subcontractors and property developers. It could therefore be argued that these actor types perceive the dynamics in the supply chain differently.

For driver categories, a comparison between actor types in the construction chain resulted in the following findings. Building on the conclusion that subcontractors and property developers experience a lot of barriers in the market and networking category, it is also true that these two actor types perceive this category to hold a lot of drivers in the pursuit of sustainability in the supply chain. Again, for main contractors it was found that the market and networking category was not mentioned as much compared to the other two actor types. Instead, they identify the organizational category to be an important driver category.

For both barriers and drivers, it was found that subcontractors and property developers focus on the market and networking category, indicating they look more at the supply chain compared to main contractors. For main contractors, it seems they focus more on regulations, institutional barriers and drivers from within their own organization.

A comparison between barriers and drivers for internally and externally developed projects revealed that, for most categories, the mentioned barriers and drivers were mentioned in approximately the same quantity for both internally and externally developed projects. There were no outstanding differences found in the amount of identified barriers and drivers for both project types. This finding implies that there is no real difference in the barrier and driver categories experienced in the supply chain based on whether a project is developed internally or externally.

Furthermore, a co-occurrence analysis was conducted that focused on how often different barrier and driver categories were mentioned together in the interviews. When certain categories are mentioned jointly by the actors, this could indicate that these categories reinforce each other either negatively (barriers) or positively (drivers). For the co-occurring barrier categories, a number of observations were made. First, the technological barrier category is regularly mentioned in co-occurrence with a number

of other barrier categories: (1) market and networking, (2) social and cultural and (3) economic and financial. This may suggest that innovative techniques may not be researched further or implemented because they are either too expensive or there may be negative cultural beliefs or attitudes towards how important innovative techniques may be. Furthermore, the social and cultural barrier category is mentioned often jointly with the market and networking barrier category. This could indicate that social and/or cultural beliefs from the actors within the supply chain (network) are hindering the implementation of sustainability in the housing construction sector.

Additionally, observations were made for co-occurring driver categories. The market and networking driver category was mentioned regularly in co-occurrence with multiple other driver categories: (1) organizational, (2) social and cultural and (3) economic and financial. The co-occurrence of the market and networking category with the organizational category could signal that organizational drivers may have a positive impact on the housing construction supply chain (network) as well as the other way around. Organizational measures may influence the way the actor operates in the supply chain, thereby prompting other actors to undertake sustainable actions as well, which in turn positively influences (the sustainable collaboration in) the supply chain as a whole. Furthermore, when actors have compatible ways of operating, they can decide to share financial burdens together. This increases the chance of seizing sustainable opportunities, such as acquiring and implementing innovative technology in the actors' operations.

Based on the identified barriers and drivers, the following practical recommendations can accelerate the transition to SSCM in the Dutch housing construction industry. First, share knowledge with all actors in the supply chain, thereby ensuring that knowledge sharing is done at the right moment in the construction process so that the relevant actor(s) therefore can operate more sustainably. This will provide opportunities for a sooner and less costly implementation of sustainability, because the later changes are made in the process, the more costly this is.

Second, develop a sustainable corporate culture that is reinforced both top-down and bottom-up in the organization. As people are hardwired to resist change in general, focusing on sustainability within corporate culture and taking measures to cope with people's resistance will help to transform employees' attitudes to generate more opportunities for sustainability. Furthermore, it is important to not only focus on the actor's own organization, but also to focus on other actors in the supply chain. Organizational changes towards sustainability can positively affect the rest of the supply chain, since a focus on sustainability from one organization can lead to selecting mainly sustainability-oriented supply chain partners. Having more than one actor focus on sustainability in the supply chain will increase chances of successfully implementing sustainability in the supply chain.

Third, some investments in sustainable operations are too high for a single actor to realize. Therefore, it is recommended that supply chain actors find effective ways to share financial burdens with each other in housing projects. This will leave more financial room to implement sustainable measures in the housing construction project, thereby decreasing the amount of emitted greenhouse gases and $NO_x$.

Fourth and last, governmental institutions draft long term visions for the environment and subsequently translate this into policy. Too often, this policy is not clear, multi-interpretable or even sets very tight implementation deadlines. To this end, it is important to implement policy that is predictable in its implementation and unambiguously formulated. Positive reinforcement measures such as a bonus point system and (tax) incentives for organizations can be employed to provide organizations with more motivation or financial resources to focus on sustainability. Conversely,

negative reinforcement measures such as increased taxes or other (financial) penalties can be used for organizations that do not meet the set standards in policy.

The research findings can be used to inform and motivate main contractors, subcontractors, property developers and governments about practical implications and the use of policy instruments to achieve a sustainable supply chain in the Dutch housing construction industry. The combination of more intrinsic motivation from all actors in the housing construction chain can pave the way for creating a sustainable way of constructing houses.

This research contributes to the academic field in a number of ways. In the first place, it confirms earlier found barriers and drivers from other industries that also apply to the Dutch housing construction industry. Moreover, barriers and drivers were uncovered that are unique to the housing construction industry. Understanding these barriers and drivers is important not only for nuancing the academic literature, but also holds value for actors' understanding of what blocks and accelerates the implementation of sustainability in the housing construction industry (including the government). Furthermore, this research included a comparison of two types of housing projects: one project where the property was developed internally by the main contractor and one where the property was developed externally. This analysis was not conducted prior to this research.

In defining the scope of this research, choices were made that impact the research design and the research outcomes. Therefore, it is inevitable that certain limitations apply to this research. First, an in-depth case study aims at understanding a phenomenon rather than drawing quantifiable conclusions. There are more actors in the Dutch housing construction supply chain than the amount of actors included in this research. Additionally, this research is based on one main contracting party, whereas there are multiple similar actor types in the Netherlands. The same is true for property developers and subcontractors. Lastly, this case study focuses on the housing construction supply chain within the Netherlands. Other countries and continents may experience different barriers and/or drivers and may use different ways of dealing with these barriers and drivers.

This research provides a starting point on which further research can continue to explore and understand the barriers and drivers in the collaboration to implement sustainability in the housing construction industry. Future research can focus on quantifying the findings from this research. Combining quantitative and qualitative research methods will provide validity and deepen the understanding on the subject matter. Additionally, research into multiple case studies can be conducted to strengthen the available qualitative data. Furthermore, it can be interesting to see what barriers and drivers occur in housing construction supply chains in other countries and continents. Analyzing barriers and drivers in other countries deepen our understanding of collaboration between different actors in the supply chain and may reveal new ways to accelerate the implementation of sustainability in the housing construction industry. Moreover, additional research into co-occurring barrier and driver categories may uncover supplementary insights into the dynamics and possible root causes of the way actors collaborate to implement SSCM.

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# Chapter 1: Introduction

Global warming has a negative impact on an expanding number of nations. The release of greenhouse gases is causing a rise in global temperature (Kweku et al., 2018). Global water distribution is one of the effects of global warming (Solomon, Plattner, Knutti, & Friedlingstein, 2009). Extremely wet weather may occur in some parts of the planet, whereas the converse may be true in other regions (Mukherjee, Mishra, & Trenberth, 2018). Heat waves may become warmer and continue longer as a result, as is currently the case in India (Glaser et al., 2016). Cities like Miami are becoming more susceptible to flooding as a result of rising sea levels (Molinaroli, Guerzoni, & Suman, 2019).

The Paris Climate Agreement, which intends to contain the warming of the globe to 1.5 degrees Celsius, was signed by state leaders of 195 nations in 2015 to lessen the effects of global warming (Salawitch, Canty, Hope, Tribett, & Bennett, 2017). Since carbon dioxide ($CO_2$) is the most frequent greenhouse gas emitted by human activity, lowering $CO_2$ emissions is the most crucial component in limiting global warming (Brander & Davis, 2012). According to the 2015 Paris Agreement, governments must reduce their $CO_2$ emissions by 50 percent by 2030.

In addition to ratifying the Paris Agreement in 2015, the United Nations' member nations also established 17 targets for sustainable development. Because the Netherlands is a member of the UN, these Sustainable Development Goals (SDGs) also apply to it (SDG Nederland, 2015). A large number of the 17 SDGs are crucial in the effort to halt the deteriorating climate and biodiversity trends. The Netherlands also implemented legislation to safeguard its biodiversity since human activity-related nitrogen ($NO_x$) pollution harms biodiversity (Rijksoverheid).

Research shows that the SDGs can only be achieved with the help of the building sector (Fei et al., 2021). Global construction accounts for 23% of all $CO_2$ emissions generated by economic activity (Huang, Krigsvoll, Johansen, Liu, & Zhang, 2018). In this regard, the Dutch construction industry is currently facing difficulties that will only get worse in the future. An illustration of such a problem is the Dutch government's regulations. The construction of homes is a special area of interest. For Dutch nationals, there is a severe lack of adequate housing options in the Netherlands (Capital Value, 2022). This scarcity highlights the pressing need for home construction. However, it is challenging for construction firms in the housing business to secure the necessary permits due to $NO_x$ and $CO_2$ emission laws. The State Council determined in November 2022 that the exception for measuring $NO_x$ emissions during construction had run its course (Bergstra, 2022). Due to the tougher restrictions that must be followed during building, this has only served to worsen the housing scarcity. Therefore, it's crucial to look into ways to lower the volume of $CO_2$ and $NO_x$ emissions that result from this stage of construction development.

The Dutch government has developed laws to minimize the emission of $CO_2$ and $NO_x$ for a number of businesses in response to mounting social and political pressure to become more sustainable, garnering significant political and public attention (BouwendNederland, 2019). The Ministry of Agriculture, Nature, and Food Quality implemented a set of guidelines in 2019 regarding a reduction in $NO_x$ emissions (Rijksoverheid, 2019). The Dutch government uses these laws to compel society to change in a way that lessens environmental deterioration. These rules must be followed by construction enterprises, compelling them to change their strategy. As a result, businesses start to set targets for themselves in an effort to become an emission-free construction company.

Achieving sustainable development depends on a variety of factors that are present during the housing construction process. The use of novel building materials and their impact on the environment have

been the subject of extensive research. In the installation of new prefabricated wooden houses, research has been done, for instance, on particularly volatile organic compounds (Schieweck, 2021). Academic research has also been conducted on greenhouse gas and $NO_x$ emissions in the construction sector (Akan, Dhavale, & Sarkis, 2017). Studies show that the supply chains in the construction sector are extremely diverse and dispersed. The government, main contractors, subcontractors, property developers, and those who will occupy the homes are just a few examples of the actors. It is crucial to take a deeper look at the collaboration between the actors in the supply chain for the housing construction industry if we are to comprehend how it can advance in sustainability. The impact of the collaboration in the housing construction supply chain on the amount of emissions is illustrated in Figure 1.

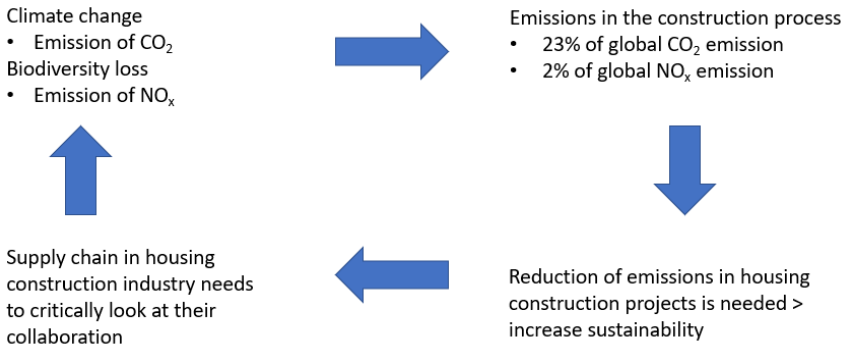


*Figure 1 Impact of (housing) construction supply chain collaboration on emissions*

It is crucial to look at how main contractors, subcontractors, and property developers collaborate in order to reduce $CO_2$ and $NO_x$ emissions during house construction projects. Additionally, it is vital to look into how they might strengthen this collaboration. This research seeks to obtain a deeper knowledge of the existing supply chain actors' collaboration in accomplishing sustainability goals through a case study by exposing the obstacles and motivators faced by representatives of these supply chain participants. It becomes obvious which collaboration areas require attention in order to mitigate (possible) hurdles and engage with driving elements more deliberately by identifying these barriers and drivers.

To comprehend the drivers and obstacles in (the deployment of) SSCM, academic research has been conducted by various academic researchers (S. A. R. Khan, Yu, Golpira, Sharif, & Mardani, 2021; Narimissa, Kangarani-Farahani, & Molla-Alizadeh-Zavardehi, 2020; Patel & Desai, 2019; Sharma, Sachdeva, & Singh, 2021). Numerous case studies into other businesses where SSCM is applicable have also been done, as well as numerous meta analyses. However, little study has been done on the factors that hinder and promote collaboration between main contractors, subcontractors, and property developers when it comes to analyzing SSCM in the (housing) construction industry. By investigating this link in the chain, this research aims to fill this gap. Not only is this relevant academically – there is also a societal need for this kind of research. As previously stated, one of the most important actors in lowering $CO_2$ and $NO_x$ emissions is the (housing) construction industry. There is still a lot of work to be done regarding reaching the SDGs and preventing climate change. Currently, subcontractors, main contractors and property developers aspire sustainability, but frequently fail to adhere to the sustainability standards defined by governmental actors. Societal efforts towards sustainability can benefited substantially by the kind of research this research provides, since there is a high demand for new homes in the Netherlands and the Dutch government prohibits the construction of new homes if contractors do not adhere to sustainability rules.

The following research question will guide the analysis:

*How can the collaboration between actors in the Dutch housing construction industry be improved in the pursuit of sustainable supply chain management?*

Four subquestions have been created to help analyze this research question. The subquestions are defined as follows:

1. Which actors in the housing construction supply chain hold the most influence in producing the majority of $CO_2$ and $NO_x$ emissions?
2. What are the known barriers and drivers during the implementation process of sustainability for traditional supply chain management in relevant major industries?
3. What are the barriers and drivers that the most influential actors in the housing construction industry encounter in their collaboration to implement sustainability in the housing construction industry's supply chain?
4. What improvements for sustainable supply chain management in the housing construction industry can be found based on the identified barriers and drivers?

The Royal BAM Group NV (from here on: BAM), a major construction firm in the Netherlands, is selected as the case study. BAM Residential, one of BAM's major subdivisions, specializes in housing and urban development projects. BAM Residential strives "to construct as clean as possible" among other things (BAM Wonen, 2020). Focusing on lowering $CO_2$ and $NO_x$ emissions should be a top priority when building sustainably and cleanly. The primary issue of BAM Residential is $CO_2$ emissions. However, there is a lot of discussion about NOx emissions in both the academic and social spheres (Sandanayake, Zhang, Setunge, & Thomas, 2015). Both types of emissions, as previously indicated, are detrimental to the climate and biodiversity and will therefore be included in this study.

BAM Residential works frequently with subcontractors and property developers, and it is crucial - though challenging - to include them in the goal of sustainability. BAM has found that property developers and subcontractors don't always work in accordance with the BAM's sustainability goals. It remains, however, unclear as to why this may be the case. This research examines how the supply chain, including BAM, may become more sustainable by examining the drivers and barriers faced by the supply chain's actors as they work together to increase sustainability.

## 1.1 Scope definition

The study focuses on Scope 3 emissions of $CO_2$ and $NO_x$ that relate to the house construction sector. Scope 3 covers all emissions throughout the entire life cycle of a product that is purchased, created, and/or sold (EPA, 2023). Given that the entire life cycle includes third parties, it follows that main contracting parties cannot directly influence all emissions produced during housing construction projects. They are a part of a complex supply chain, and this thesis will concentrate on chain actors that have a major impact on the bulk of produced $CO_2$ and $NO_x$ emissions. This research examines the collaboration between these actors by examining the obstacles and motivations they faced in their (joint) efforts to integrate sustainability in the supply chain for the house building industry.

The most significant contributors to $CO_2$ and $NO_x$ emissions during the housing construction process will be examined in this thesis. This data will be used to narrow the focus of this study by identifying the three most important actor types. Analyzing these three actor types will provide useful insights into their collaboration and it is expected that addressing the encountered barriers and formulating actionable recommendations will yield the biggest results.

A case study will be conducted on two projects, one developed internally by BAM and the other developed externally. Both projects are carried out in the Netherlands and are limited to single-family homes - there are no apartment housing initiatives involved. A property developer, a project manager from the main contracting party, and four subcontractors are all interviewed for each project.

## 1.2 Outline

This thesis proceeds as follows. Chapter 2 demonstrates the current state of academic research into sustainable supply chain management (SSCM) in the (housing) construction industry as well as other industries. Additionally, barriers and drivers from different industries will be analyzed and integrated into a concise list of categories with the uncovered barriers and drivers, thereby answering **subquestion 1**. Subsequently, this chapter will also serve to answer **subquestion 2** by analyzing the actors that hold substantial influence over the majority of producing the most $CO_2$ and $NO_x$ emissions during the construction of houses.

Next, Chapter 3 discusses the methodology that is used to carry out the research. This chapter will elaborate on the research methods used in this thesis and describe the case that is studied in this research.

Chapter 4 proceeds by analyzing the barriers and drivers that emerged during the interviews with representatives of the main actor types, thereby aiming to answer **subquestion 3**. In this chapter, it becomes clear how often different actor types encounter specific barriers and drivers, if there are any differences in barriers and drivers between the supply chains for internally and externally developed housing projects, as well as correlations between barrier and/or driver categories. The chapter concludes by a synthesis in which the findings on the different barrier and driver categories are integrated and interpreted.

Subsequently, Chapter 5 elaborates on how this research relates to previous academic research and illustrates the contribution of the current study to the academic field. Additionally, possible research limitations are discussed.

Furthermore, practical recommendations are presented in Chapter 6. These recommendations are improvements that provide an answer to **subquestion 4**. For each actor type, recommendations are made that are based on a combination of the most actionable recommendation, the most important findings regarding the barriers and drivers, as well as considerations regarding addressing possible underlying root causes of the barriers found in the research.

The conclusion in Chapter 7 will serve to briefly recollect the answers to the subquestions before answering the **main research question**. Thereafter, it provides possible avenues for future research.

# Chapter 2: Theoretical framework

This chapter demonstrates the state of academic research regarding (sustainable) supply chain management and illustrates the current supply chain for the housing construction industry, wherein the most important actors are identified. This way, in paragraph 2.2, the first subquestion will be answered: *Which actors in the housing construction supply chain hold the most influence in producing the majority of $CO_2$ and $NO_x$ emissions?*

Additionally, this chapter includes analysis of the theoretical barriers and drivers for implementing sustainable supply chain management (SSCM) that were found in other major industries, since there has been no research yet into the barriers and drivers in the housing construction industry until now. Hereby, paragraph 2.3, aims to answer the second subquestion: *What are the known barriers and drivers during the implementation process of sustainability for traditional supply chain management in relevant major industries?*

## 2.1 Supply chain

### 2.1.1 Supply chain management

Supply chain management (SCM) entails managing the flow of goods and services that includes processes to transform raw materials into final products (Fernando., 2022). To maximize customer value and to gain competitive advantage in the marketplace, it is necessary to actively streamline a company's supply-side activities. SCM is paramount to help a company to achieve its strategic goals. During the production phase, product quality needs to be checked as product high quality results in a lower risk of dissatisfaction in business relations. Besides production, SCM aims at decreasing product shortages, thereby ensuring satisfactory delivery of the product to the customer. Managing all aspects of the supply chain adequately will improve profit margins, as well as good relations between the company and customer.

In SCM, five stages can be distinguished: planning, acquiring raw materials, manufacturing, delivery, and returning the product. These stages will be described further hereafter.

***Planning***

Planning is key in establishing a well-functioning supply chain. Determining the demands and needs of the target customer is the first step in the planning process. Having identified these demands and needs, a company can work towards meeting the corresponding criteria of the desired product by optimizing the supply chain. The amount of products that can be produced is closely related to the extent of raw materials that has to be acquired. Moreover, the capacity and limitations of staff and factory needs to be estimated. These different pieces of information need to be taken into consideration in order to deliver the right product in time and in the necessary amounts. Therefore, the planning stage is essential to ensure that the next stages in the supply chain progress smoothly.

***Acquiring raw materials***

In order to acquire the adequate raw materials for the manufacturing stage, a company needs to work closely with other actors in the supply chain. One way to ensure this acquisition is to draw a contract with a third party (subcontractor) to deliver these materials when the company cannot produce these themselves. When working with a subcontractor, the lead time and ways that the supplying subcontractor fulfils the requirements of the company needs to be taken into consideration. Generally, SCM contains the following sourcing requirements:

- Raw materials meet the specifications for the manufacturing stage to develop the right products.
- The paid prices correspond with market expectations .
- The subcontractor is provided with flexibility to deliver emergency materials after unforeseen events.
- The subcontractor has proven to deliver goods in a timely manner and in good quality.

***Manufacturing***

During manufacturing, raw materials are transformed into new products by employing labor, machinery and other external workforces. Delivering the final product is the primary goal of this stage in the supply chain. This, however, is not to say it is the final stage of SCM. There are multiple subtasks in the manufacturing process such as assembling, testing, inspecting and packing the product. The company and potential subcontractors need to be aware of limiting waste and other factors that can lead the supply chain to deviate from initial plans.

***Delivering***

Having produced a final product, the next step is to deliver it to customers. Up until this moment, the customer has not had a chance to interact with the product. Solid SCM is key to hand the product to the customer, which entails implementing a strong logistic network to guarantee an optimized delivery of the produces products in a timely, safe and inexpensive manner. This also implies that it is important to not rely on one delivery method, but to have a backup plan or to make use of multiple distribution procedures.

***Returning the product***

When the product is delivered to the consumer, the customer has two options. They can choose to keep and use the product if they are satisfied with the product or they can return the product. The company has to guarantee that the product can be returned and that the customer receives a refund. In strong SCM processes, there is an important role for identifying the underlying cause(s) for returning a product, e.g. defect or expired products. If this is not evaluated by the company, it is highly likely that products will continue to be returned. This, in turn, will cost the company more money than investigating the supply chain and improving SCM processes to meet the customer's demands and needs.

### 2.1.2 Sustainable supply chain management

In 2022, humanity used 175% of all biological resources that planet earth can (re)generate in an entire year (EOD). Every year, this percentage increases: in 1971, 100% of all biological resources for the year where fully used on December 25. In 2000, this was reached on September 25, whereas for 2022, July 28 marked this moment. With these kinds of insights, there is an increasing awareness that change is needed. Sustainable supply chain management (SSCM) refers to the consideration of sustainable solutions in the supply chain to address environmental issues. In academic literature, numerous definitions persist, of which a non-exhaustive overview can be found in Table 1. In this study, SSCM is defined as follows (Seuring & Müller, 2008):

> *"(…) The way of managing finance, information and material flows as well as the collaboration amongst the enterprises all across the supply chain with an aim to deliver goals of attaining sustainable development which itself includes Economic, Social and Environmental development."*

The rise of urbanization and globalization shifted the focus to finding more sustainable solutions for traditional ways of working within SCM. In order to succeed in competitive market environment and to keep and improve the current market share, SCM needs to move towards SSCM. This results in reevaluating performance-oriented business practices to explore new possibilities to lead the way in this development (Silvestre, 2015).

*Table 1 Definitions of sustainable supply chain management (Sharma et al., 2021)*

| Author and Year | Definition |
|---|---|
| Khan et al. 2017 | "Sustainable Supply Chain management is being referred to as the process of converting input into out with the effective resource utilization and improved societal and environmental life". |
| Al Zabbi et. al 2013 | "SSCM is a way which depicts plan of a firm for mitigating, detecting and responding to the global risks. (Risks involves marketing and SC deliberations which further includes R&D, decisions of market, manufacturing and sourcing, complexities, transportation, managing of talent, substitute source of energy." |
| Ahi and Searcy 2013 | "SSCM is Supply Chain in which there is an integration of environmental and social focus alongside with economic considerations where every system throughout the business is so designed to work in an efficient manner which includes material flow, information flow and the Capital flow which are linked with the raw material purchase , Manufacturing and the supply of goods/services whose ultimate goal is to increase and enhance the profitability to stakeholders as well as the competitiveness with resilience in long/short run." |
| Wittstruck and Teuteberg 2012 | "SSCM is the addition of the conventional Supply chain with the Social and environmental practises" |
| Seuring and Beske 2010 | "SSCM has been narrated as planning and managing of various steeps across the Supply chain consisting of sourcing and procuring materials/services, conversion and logistical services at every stage of manufacturing in a closed loop with an eye on environmental and social development." |
| Carter and Rogers 2008 | "SSCM is integrating and achieving Social, environmental and economic goals of an organisation which further enhances the economic performance in longer run." |
| Seuring and Muller 2008 | "SSCM has been described as the way of managing finance, information and material flows as well the cooperation amongst the enterprises all across the Supply chain with an aim to deliver goals of attaining sustainable development which itself includes Economic, Social and Environment development." |
| SK Srivastava 2007 | "GSCM as a way of integration of environmental thought into each phase of Supply chain starting with product design to material sourcing to process of manufacturing to delivery of final product lastly to the end of the product(disposal) after its full use." |

#### *2.1.2.1 Pillars of sustainability*

Building on the definition of SSCM, it is also important to explore the topic of sustainability. There are three areas of responsibility for companies, as they "represent the elements of a new equation for assessing and expressing the worth of a company in terms of its 'sustainability'" (Elkington, 1998). These three areas constitute the pillars of a corporate sustainability strategy (Andrew Beattie, 2021): environment sustainability, economic development and social development. These pillars can be integrated within the traditional SCM model to form SSCM, which is shown in Figure 2.

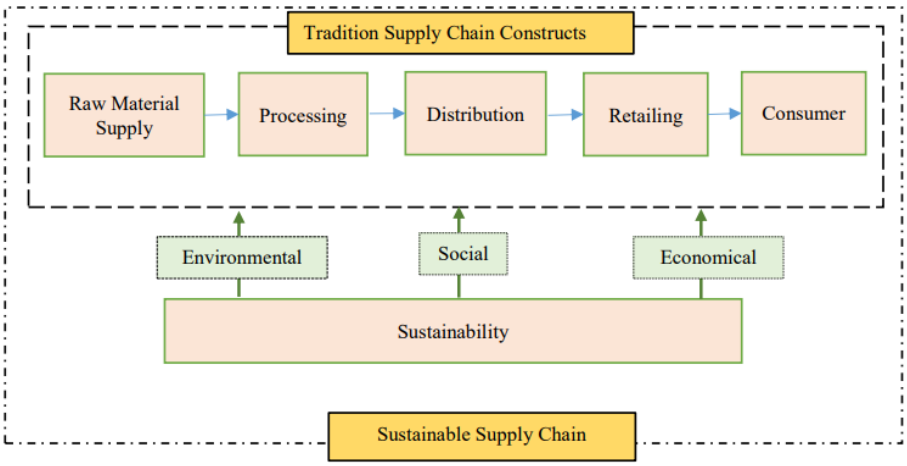


*Figure 2 Integrated sustainable supply chain (Sharma et al., 2021)*

**Environmental sustainability**

Environmental sustainability constitutes the first pillar in Elkington's sustainability model and is the focus of this thesis. This pillar focuses on the way business activities and decision making have an impact on the environment. It looks at "processes, systems and activities that reduce the environmental impact of an organization's facilities, products and operations" (Golka, 2020). This often draws the majority of public attention, leading many companies to focus on reducing their carbon footprint, packaging waste, use of water, and other aspects damaging the environment. This often results in a simultaneous financial positive outcome, for example when a company focuses on reducing their packaging waste. Finding new ways and eliminating waste can result in finding more ecofriendly packaging materials, such as recycled cardboard or plastics, which can lead to reduced costs when recycle methods are optimized. The main challenge for companies focusing on this pillar is that there are hidden costs or externalities that are not reflected in the price paid by the customer (Purvis, Mao, & Robinson, 2019). The total costs of $CO_2$, land reclamation, waste water, and waste in general are hard to calculate. Benchmarking can provide a good method to track and quantify the amount of produced waste.

**Economic development**

Economic development constitutes the second pillar in the sustainability pyramid and refers to "maintaining honest and transparent accounting practices and regulatory compliance" (Andrew Beattie, 2021). To become (more) sustainable, a company has to be profitable. This does not mean that the economic pillar is more important than the other two pillars. In fact, this pillar is not about making profit at any cost. Instead, it is concerned with risk management, proper governance and compliance. Because of the governance aspects in the pillar, it is sometimes referred to as the governance pillar, referring to top management aligning themselves with shareholders' interests on the one hand, while simultaneously aligning with interests of customers, value chains and the company's community.

**Social development**

The third pillar of corporate sustainability strategy comprises of social development, which refers to "the practices that benefit the company's employees, consumers, and the wider community" (Andrew Beattie, 2021). The support from these actors is key for sustainable companies to stay in business and is based on, among other things, the way employees are treated, as well as being a responsible partner and member of the local and global community. For employees, companies can invest in strategies on

retention and engagement, whereas for community engagement, they can focus on societal ways to give back to the community (e.g. scholarships and investing in local projects). Globally, companies should bear in mind how its supply chain works. Questions around child labor, fair wages and safe working environments are relevant in this regard.

The scope of this research revolves around the first pillar of sustainability: environmental sustainability. The focus on the collaboration between actors in the housing construction supply chain aims at identifying how and which sustainability measures need to be implemented to limit the industry's impact on the environment in their activities and decisions during housing construction projects. The research looks at what processes, systems and activities are in place that block or accelerate the implementation of sustainability (measures) in the supply chain. The next paragraph will elaborate on what this focus means for the housing construction supply chain.

## 2.2 The housing construction supply chain

### 2.2.1 Scopes of greenhouse gas emission (Greenhouse Gas Protocol)

The Greenhouse Gas Protocol is a leading corporate accounting standard for greenhouse gas emissions (which includes $CO_2$ and $NO_x$) and categorizes greenhouse gas emissions into three scopes (CarbonTrust). The scope of this study is to analyze the collaboration between supply chain actors in the housing construction industry, which means that the research focuses on actors that are involved in Scope 3.

- Scope 1 concerns direct emissions from sources that are controlled or owned by the company. The following emissions are included: fuel use to heat up offices, work spots and construction sites, fuel use on construction sites, fuel use for lease and company cars.
- Scope 2 emissions are indirect greenhouse gas emissions deriving from "the purchase of electricity, steam, heat, or cooling. (…) They are accounted for in an organization's GHG (greenhouse gas) inventory because they are a result of the organization's energy use." (EPA)
- Scope 3 includes all indirect greenhouse gas emissions occurring in the upstream and downstream activities of a company. These activities are hard to control, since one company cannot directly control the emissions produced by other chain partners and there is a high level of complexity in the supply chain.

The actors involved in the existing housing development chain operate in a fragmented manner. They are, in a way, islands related to each other in some way since each actor in this chain has its own responsibility and behaves accordingly. The collaboration between the property developer, main contractor and subcontractor is the subject of this research in an effort to make the housing construction supply chain more sustainable. For the purpose of obtaining materials or services, the main contractor will employ subcontractor, e.g. a concrete manufacturer, which is referred to as a first tier contractor (Wilhelm, Blome, Bhakoo, & Paulraj, 2016). These first tier subcontractors deliver products for which they rely upon other suppliers, e.g. cement suppliers. This is referred to as second tier subcontractor, which will not be considered part of this study's scope (Wilhelm et al., 2016). A red dotted line in Figure 3 demarcates the participants in the housing construction supply chain that are subject to the research in this study.

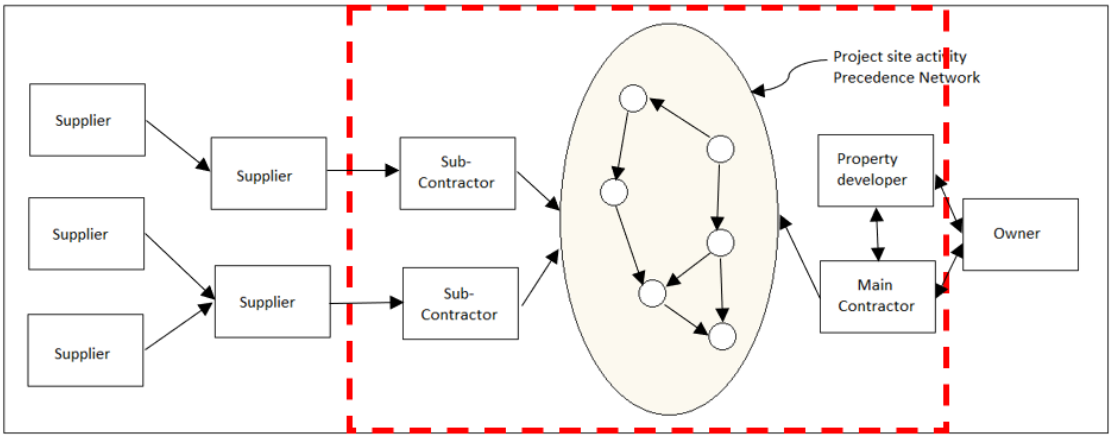


*Figure 3 Supply chain for construction industry (adapted from (O'Brien, London, & Vrijhoef, 2002)*

### 2.2.2 Property developer

A key player in the cycle of housing building is the property developer. The design of the construction project is the property developer's responsibility. The choice of materials to be utilized later on during in the construction project is an important topic where the property developer holds major influence. The main contractor and the subcontractor carry out the design's specifications and will use less sustainable materials if the design or budget does not allow sustainable solutions (Desivyana, Farmakis, Cusumano, & Rempling, 2023). This will result in more emissions, when a property developer gives little thought to the adoption of sustainable building items in the design. When a property developer creates a design that incorporates a lot of sustainable materials, it translates into the main contractor and subcontractor will build with more sustainable products, resulting in lower emissions (Glass, Achour, Parry, & Nicholson, 2011).

### 2.2.3 Main contractor

Main contractors will interact with the property developer and the first-tier subcontractors in their role. They operate as the go-between between the property developer and the subcontractors (Vrijhoef & Koskela, 2000). The entire construction process might become sustainable if the main contractor is able to communicate sustainability information from one partner to the next (Glass et al., 2011).

### 2.2.4 Subcontractor

Delivering the commodity or service specified in the contract is where the subcontractor comes into play. There are greenhouse gas and $NO_x$ emissions that occur during the production of goods or the delivery of services that are bad for the environment and biodiversity (Yoro & Daramola, 2020). It is critical that the subcontractors are involved in the research and collaboration in order to increase the sustainability of the housing construction chain.

#### *2.2.4.1 Life Cycle Assessment in the housing construction industry*

To determine the most important and influential actors in the supply chain of the (housing) construction industry, previously conducted Life Cycle Assessments (LCAs) can be consulted. LCA evaluates the environmental impact of products or services, considering processes, materials and use of energy throughout their entire lifecycle (Simonen, 2014). In this analysis, LCAs from the construction industry in general and the housing construction industry are taken into account, since the production materials for both industries are similar. In Greece, a study into embodied $CO_2$ in the construction of Hellenic dwellings found that the three materials that emitted the vast majority of $CO_2$ emissions were steel, concrete and brick, as shown in Table 2 (Syngros, Balaras, & Koubogiannis, 2017).

*Table 2 ECO2 intensity contribution of the top 8 dominant construction material (ECO2 impact)*

| | Percentage $ECO_2$ [%] | | | | | $ECO_2$ intensity [$kgCO_2/m^2$] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material** | **A** | **B** | **C** | **D** | **Average** | **A** | **B** | **C** | **D** | **Average** | **$C_{ECO2}$[17]** |
| Steel | 33.3 | 24.5 | 33.7 | 25.5 | 29.3 | 919 | 600 | 1290 | 921 | 933 | 2.29 |
| Concrete | 22.8 | 23.4 | 28.6 | 22.7 | 24.4 | 630 | 573 | 1095 | 820 | 779 | 0.14 |
| Brick | 14.9 | 16.5 | 11.3 | 17.5 | 15.1 | 411 | 404 | 433 | 632 | 470 | 0.23 |
| Lime | 6.9 | 7.5 | 5 | 8.8 | 7.1 | 191 | 184 | 191 | 318 | 221 | 0.76 |
| Tiles | 4.6 | 4.3 | 7.4 | 6.5 | 5.7 | 127 | 105 | 283 | 235 | 188 | 0.74 |
| Wood | 0 | 4.7 | 4.9 | 8.1 | 4.4 | 0 | 115 | 188 | 293 | 149 | 0.72 |
| Aluminum | 5.7 | 7.3 | 0 | 1.5 | 3.6 | 157 | 179 | 0 | 54 | 98 | 8.16 |
| Plaster | 3.2 | 3.9 | 2.8 | 3.6 | 3.4 | 88 | 96 | 107 | 130 | 105 | 0.12 |
| **(Total)** | (91.4) | (92.1) | (93.7) | (94.2) | (92.9) | | | | | | |

Additionally, a study in the Republic of Korea (South Korea) confirmed these findings in a LCA on the construction of apartments. In this study, it was even found that 82 percent of the total $CO_2$ emissions during construction were caused by steel and concrete, as can be found in Figure 4 (Jeong, Lee, & Huh, 2012). The fact that steel and concrete were together responsible for more than half the amount of emitted $CO_2$, was also found by a LCA of an office building in Thailand (Kofoworola & Gheewala, 2008). Based on these findings, steel, concrete and brick will be discussed briefly.

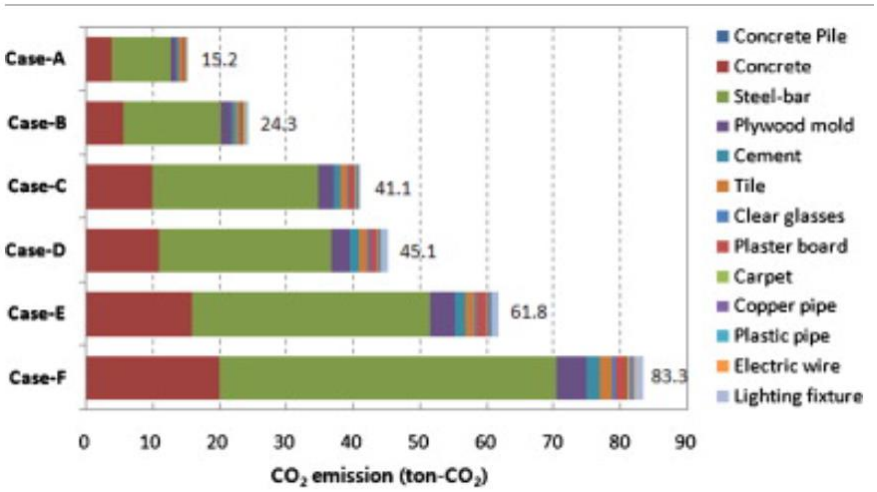


*Figure 4 Construction materials and their CO2 emission (ton-CO2)*

### *2.2.4.2 Steel*

Steel is an artificial construction material that consists of iron and carbon and is used in many different constructions. The maximum amount of carbon in steel is 1.8 percent, which is much lower than the amount of carbon in cast iron. Cast iron is casted in a mold and is more fragile since the amount of carbon lies between 1.8 and 4.3 percent (Elliott, 1988). Unlike cast iron, steel can be processed when it is heated because it is far less fragile, providing a reliable construction material for a variety of construction projects, including housing projects. Besides using steel on the outside of a construction, steel is also used in reinforced concrete structures (Park & Paulay, 1991).

The first step in the production process of steel takes place in iron ore mines (Yellishetty, Ranjith, & Tharumarajah, 2010). The iron ore is melted in a blast furnace with other materials such as coke and limestone. This process results in a product called pig iron, which consists of polluting substances like

sulfur and phosphorus. These substances have to be separated from the pig iron by means of a converter (Kijac & Borgon, 2008). The converter has an average temperature of 1650 degrees Celsius and during this process, almost 100 percent oxygen is blasted into the molten pig iron. In this process, the oxygen and carbon produce CO and $CO_2$, thereby separating from the molten iron (Gielen, 2003). The amount of carbon in the molten iron drops under 1.8 percent, which results in steel (Gu, Poon, & Shiflet, 2007). During this process, a small portion of the oxygen will react with the steel. To remove this small amount of oxygen from the steel, manganese, silicate or aluminum is added. Then, a substance of created oxides is floating on the molten steel. This polluting layer is called slag and has to be removed to end up with purified steel (Lu, Bai, & Shan, 2008). The purified steel will be casted in the desired molt with a continuous cast process.

Iron ore is not the only source to manufacture steel. 25 percent of all manufactured steel originates from recycled steel. Steel from buildings that have passed their technical lifespan are recycled to create new steel. This steel will be melted in a blast furnace and after it is purified, the steel can be reused again for construction (Björkman & Samuelsson, 2014).

#### *2.2.4.3 Concrete*

Concrete is an artificial construction material that can be used for a variety of construction projects, e.g. to construct a building or bridge components. Given its many potential purposes, concrete is one of the most used construction materials in the world (Mondal, Das, & Chakraborty, 2017). Concrete consists of a composition of cement and aggregates. The aggregates include a mixture of sand, gravel and crushed stones. Materials that can be used besides the aggregates are fly-ash (residual product produced by coal-fired power plants) and slags (residual product produced during the production of steel) (Malhotra, 1993; Vijayaraghavan, Jude, & Thivya, 2017). Cement consists of calcium-silicates that create a strong solid network after a chemical reaction with the right amount of water. Since concrete has many potential purposes, the amount of cement and aggregates differs per construction project, referring to compressive strength, environmental specifications, endurance and other requirements (Felekoğlu, Türkel, & Baradan, 2007). The process of the production of a concrete construction in general is shortly described below.

Aggregates, cement and water are mixed in the right proportions that adhere to the construction project's concrete requirements. When the concrete is mixed, it is placed in a cement truck and transported to the construction location. After pouring the substance in position, the densification process takes place. It is important, however, that the mix of aggregates remains distributed equally during the hardening process. Therefore, it is vital that the vibrations of the tube in the concrete is done excessively. After the densification process, the concrete has to be protected against dehydration, since dehydration of concrete can lead to an unwanted tensile strength which result in cracks (Fu, Wong, Poon, Tang, & Lin, 2004). The protection is carried out by adding water on the surface of the concrete. The process of hardening of concrete is a exothermic reaction (Wang et al., 2020). To cool concrete after the exothermic reaction, tubes are integrated in the substance, allowing cool water to flow through the concrete.

#### *2.2.4.4 Brick*

Brick is a multi-purpose artificial construction material that can be used for the construction of walls and roads, among other things. The first bricks date from 7000 BC (A. Khan & Lemmen, 2013). Bricks consist of clay, sand and water (Xu, Yan, Xu, Ruan, & Wei, 2014). Different colors of sand can be added to create the desired brick color. The first bricks were formed by hand, but then molts were created to form bricks of the same size. This process was quicker and resulted in a more constant shape and so

this choice increased the applicability of the brick for constructions (Dalkılıç & Nabikoğlu, 2017). The process of the production of bricks in general is shortly described below.

First, clay needs to be collected in the bed and the floodplains of a river. Then, the clay is transported to a depot at the brick factory by ship, train or truck. Subsequently, a shovel from the factory carries the unfiltered clay to a machine that removes pieces of metal and other impurities. Next, clay is grinded and kneaded to create a homogeneous product to ensure that bricks have the same structural strength (Zhang, 2013). There are many different colors of sand in the world that can be used to determine the color. When the clay is mixed with the right amounts of water and sand, the clay will be pressed into molds. After the pressing procedure, the formed clay is removed from the mold and placed on a drying rack to dry in a dry tunnel for two to four days before in can enter the oven. When the amount of water in the brick is too high, there is a high risk of cracks in the brick. After the drying process, the clay mixture is baked in an oven at a temperature of 1250 degrees Celsius (Zhang, 2013). The oven is heated with gas burners that will produce a constant heat during the baking process. During the baking process, greenhouse gasses like $CO_2$ are emitted (Murmu & Patel, 2018).

#### *2.2.4.5 Construction site preparation*

The above described materials are responsible for most of the emissions related to construction materials. However, besides these construction materials, the activities on the construction site are responsible for emissions. About 71 to 85 percent of all emissions during construction are related to activities on the construction site, with the vast majority thereof being emitted during bulk excavation (Marshall, Rasdorf, Lewis, & Frey, 2012). Therefore, it is of importance to involve parties that are responsible for the bulk excavations on the construction site in the research regarding the collaboration to become more sustainable.

## 2.3 Barriers and drivers for SSCM in other industries

Over time, SSCM has become increasingly important for a variety of industries. Several studies have conducted research into identifiable barriers and drivers in implementing SSCM for a number of industries, yet this is not the case for the housing construction industry. Nonetheless, research into the barriers and drivers for SSCM in other industries provide a valuable starting point to identify the most important barriers, drivers and overarching categories. In Appendix A, the barriers and drivers can be found from other studies in the car industry, chemical industry, manufacturing industry, clothing industry, steel industry and construction industry. The barriers and drivers in this table were used as starting point for the interviews that were conducted for this study. Chapter 3 will further elaborate on these interviews and the way that these barriers and drivers were used.

To have a better understanding of these barriers and drivers, they are divided into categories. Drawing on previous SSCM meta-analyses by (De Jesus & Mendonça, 2018) and (Walker, Di Sisto, & McBain, 2008), six categories were identified: (1) Economic & financial, (2) Market & Networking, (3) Organizational, (4) Regulatory & institutional, (5) Social & cultural, (6) Technological. A brief description of these categories will be provided in Table 3.

*Table 3 Barrier and driver categories*

| Category | Description |
|---|---|
| Economic & financial | Refers to monetary barriers and drivers, including investments, return on investment and (uncertainty of) profit |
| Market & networking | Includes market dynamics and actors, among others competitors, market (un)certainty, suppliers, (sub)contractors, other supply chain actors |
| Organizational | Considers "internal" factors, includes (top) management commitment and employee involvement |
| Regulatory & institutional | Includes legislative measures, effectiveness of legal/governmental support system, incentives, institutional (government) standards |
| Social & cultural | Refers to social awareness, customer and employee behavior and (business) routines |
| Technological | Includes the (un)availability of (in)appropriate technology, its design and technical knowledge and training |

# Chapter 3: Methodology

This chapter discusses the research methodology. The main approach to conduct this research is a qualitative case study, which builds upon the theoretical foundations as studied in Chapter 2. Semi-structured interviews have been conducted to obtain the necessary data for the analysis of barriers and drivers. The case study format was chosen since it is a tool that can provide a deeper understanding of the real-world context of the housing construction supply chain, and, more specifically, the collaboration between main contractors, subcontractors and property developers.

## 3.1 Literature study

The research commenced by means of a literate study that can be found in Chapter 2. In this chapter, two subquestions were analyzed (i.e. subquestion 1 and 2). To answer subquestion 1, the literature study focused on determining how industries other than the housing construction industry apply SSCM. Through this analysis, known barriers and drivers influencing the implementation of SSCM in other industries were mapped out, thereby providing a starting point for the interviews in the next phase.

To answer subquestion 2, life cycle assessments of projects in the global housing construction industry were examined. With this information, the most influential actors were identified that hold major influence regarding the majority of produced $NO_x$ and $CO_2$ emissions. It was found that main contractors, subcontractors and property developers were the most important actor types, which translated into these actor types being approached to participate in interviews. Although there are more actor types involved in the housing construction's supply chain, this thesis is subjected to a limited time span, therefore not all actor types have been included in this research. In this thesis, the top three most influential actor types have been chosen, since it is expected that having influential actors undertake steps that address proven barriers and drivers will yield the biggest results in implementing sustainability in the housing construction's supply chain. Moreover, in analyzing the supply chain, it became clear that not only actors in the construction phase have a big influence on the amount of emissions during construction, but that design choices also bear significant consequences. This is why property developers in the design phase of the construction project are also included in the analysis.

Scientific search engines, e.g. Google Scholar, Scopus, ScienceDirect, and WorldCat, were used to find relevant academic sources. Keyword search was used to source through different journals instead of journal search, since there is no journal available that would cover the broad amount of topics that this thesis touches upon. The main keywords that guided the online search included: main contractor, subcontractor, (property) developer, sustainability, SSCM, barriers, drivers, decarbonization, $CO_2$ reduction, nitrogen reduction, transition, scope 3, housing construction.

Potentially relevant articles were selected based on the article's abstract and later analyzed closely to determine the relevance for this thesis' research. Subsequently, the articles were read and categorized according to the outline of the theoretical framework.

## 3.2 Case study design

### 3.2.1 Research design selection

There are five ways to conduct research (Hollweck, 2015): historical analysis, archival analysis, experimenting, surveying and case studies. As Hollweck explains, a method should be chosen in accordance with the research questions and the purpose of the study in question. The current research does not control behavioral events (experiments) and is focused on contemporary events instead of

historical ones (historical and archival analyses). This leaves two methods: surveys and case studies. Both methods apply to the current research – the case study provides a real life context on which theory will be applied. Moreover, surveys (in the form of interviews) will serve the purpose of finding out the true barriers and drivers by people in the field.

### 3.2.2 Interviews

Three types of interviews can be distinguished:

1. Unstructured interview: the format of this interview does not involve predetermined questions, which leads to an open conversation that moves in a direction that is created in the moment. The shape of the interview is based on the spontaneous interaction of the respondents and the researcher (Creswell, Hanson, Clark Plano, & Morales, 2007).
2. Structured interview: the format of this interview consists of questions that are predetermined and structured. All respondents receive the same open-ended questions during the interview (Turner III, 2010).
3. Semi-structured interview: the format of this interview involves predetermined, open-ended questions. There is room for additional questions during the interview as they may arise from the conversation between the interviewer and the respondent (DiCicco-Bloom & Crabtree, 2006).

A semi-structured interview combines the best of the structured and unstructured formats of interviews (DiCicco-Bloom & Crabtree, 2006). The semi-structured interview ensures that the main topics of focus are covered while the possibility to steer the interview in other directions remains. It also allows the responses of the respondents to be unbiased and unguided by the researcher's assumptions and directions. The semi-structured interview type is the most appropriate for this research, since there are certain topics to uncover during the interviews that require a light structure for the interviews. The semi-structured format, however, leaves room to delve deeper into interesting topics to gain a better understanding of the dynamics of the discussed experiences.

Choosing the unstructured interview type will result in inconsistent interviews (Wildemuth, 2016). This makes it hard to analyze obtained data and might lead to unreliable assumptions and conclusions (Creswell et al., 2007). The exploratory nature of this research also makes the structured interview type not suitable for this study because empirical data from the case study is not exactly determined and known beforehand (Turner III, 2010).

Regarding the interview questions, these were formulated based upon (McNamara, 2009) recommendations for effective interview questions:

1. All wording is open ended.
2. Questions are formulated neutral (as far as possible).
3. Ask questions one at a time.
4. Use unambiguous language in the questions.
5. Ask "why" questions carefully.

The next step is to provide the semi-structured interview with appropriate content. The content is prepared by asking questions that focus on the categories that were obtained from the literature review. These categories, in which the barriers and drivers that were found in earlier studies are included, provide a good basis for the preparation of this interview. Table 4 shows these categories and their respective barriers and drivers (from other industries). These barriers and drivers were used to analyze the interview data by providing a set of closed codes. More information on closed and open coding can be found later in this chapter, in section 3.3. Additionally, the setup for the semi-structured interviews can be found in Appendix B.

*Table 4 Overview of barriers and drivers*

| Category | Barriers | Drivers |
|---|---|---|
| Economic & financial | • Uncertainties in market competition<br>• Lack of money to invest (investment is too high) | • Reduction of costs in supply chain by minimizing consumption of resources<br>• Create a market pull<br>• Develop internal financing resources<br>• Tax incentive by the government<br>• Look for opportunities in the long run |
| Market & networking | • Resistance of suppliers to implement certain clean technology practices<br>• Lack of understanding and knowledge on SSCM among organizations in the supply chain<br>• No responsibility taken by involved parties<br>• Complexity in the supply chain<br>• Lack of demand from customers for sustainable products<br>• Lack of promotion of sustainable products<br>• Lack of awareness among stakeholders<br>• Preferences of suppliers/ institutional buyers<br>• Insufficient environmental competencies (in market)<br>• Wide communication gap (in market) | • Customer awareness and demand for sustainable products<br>• Decrease infrastructure strain (from market)<br>• Create environmental collaboration between main and subcontractor<br>• Public pressure<br>• Create awareness among involved parties<br>• Public funding<br>• Develop collaboration agreements<br>• Develop infrastructure support and facility for sustainable operations |
| Organizational | • Lack of implementing green practices<br>• Lack of skilled manpower to implement innovation<br>• Uncertainty of innovation process<br>• Inability in the organization to align their goals and work on it<br>• Lack of top management commitment<br>• Insufficient environmental competencies (in organization)<br>• Inadequate proactive plans<br>• Wide communication gap (in organization)<br>• Lack of employee welfare package<br>• Lack of worker's training on sustainable operations | • Commitment of top management<br>• Improve image of industry<br>• Create sustainable corporate culture<br>• Ensure environmental competencies<br>• Integrating sustainable operations in proactive plans |
| Regulatory & institutional | • Lack of government support system<br>• Not enough rules and regulations set by the government<br>• Lack of demand from government for sustainable products<br>• Lack of awareness among stakeholders<br>• Preferences of suppliers/ institutional buyers<br>• Insufficient environmental competencies | • Support system by the government with regulations and effective legislation<br>• Legal requirements<br>• Tax incentives by government<br>• Create awareness among parties<br>• Develop collaboration agreements |

| | | |
|---|---|---|
| | • Wide communication gap (government) | • Integrate sustainable operations in proactive plans |
| Social & cultural | • Low quality of employees<br>• Wide communication gap (societal)<br>• Lack of worker's training on sustainable operations | • Public pressure<br>• Involvement of employees<br>• Look for opportunities in the long run |
| Technological | • Implications of costs<br>• Inappropriate technology to improve<br>• Stick with traditional technology<br>• Companies cannot measure amount of emissions<br>• Technical obstruction (difficult to work in different ways)<br>• Lack of sustainable waste management | • More IT implementation<br>• Information sourcing about green technologies<br>• Create a technology push<br>• Access to advanced technology for sustainable operations<br>• Good measurement data<br>• Integrate sustainable waste management |

### 3.2.3 Respondent and project selection

In the literature study, subquestion 2 aimed at determining which actors are relevant for the research. It was found that main contractors, subcontractors and property developers are important when it comes to making the construction chain of houses more sustainable. Since BAM uses both internal and external property developers for their construction projects, it is interesting to see if there are differences between these types of projects.

Twelve interviews were conducted among a set of ten respondents, which will be explained later in this section. These respondents were selected based on their roles within the case study of the two housing projects. In Table 5, the types of respondents are listed and characterized. Due to confidentiality, all data that can possibly lead to identification of the interviewed parties is anonymized.

*Table 5 Respondent types*

| **Phase** | **Respondent description** | **Number of interviewed parties** |
|---|---|---|
| Design | Property developer | 2 |
| Construction | Main contractor | 2 |
| Construction | Subcontractor | 8 |

For all the listed types of interviewed actor types, an internal party was interviewed, as well as an external organization. That translates into two interviewed parties for each type of respondent. The respondents that were interviewed as property developers representatives had to be directly involved and be familiar with the actors in the specific construction project. The respondents that were interviewed as main contractor representatives were chosen based on their role in the project – they had to be in direct contact with subcontractors so they could share first-hand experiences of their collaboration. The interviewed subcontractors were suppliers of brick, concrete, steel, as well as parties that are responsible for (construction) site preparation. The steel supplier and the company responsible for the construction site preparation were contracted by the main contractor for the internal as well as the external project. Therefore, it was decided to conduct a double interview

with representatives from these companies. This is why there are twelve interviews among a set of ten respondents. To avoid misunderstanding, both the steel company and the construction site preparation company are there labelled with a blue star in the overview that can be found in Figure 5.

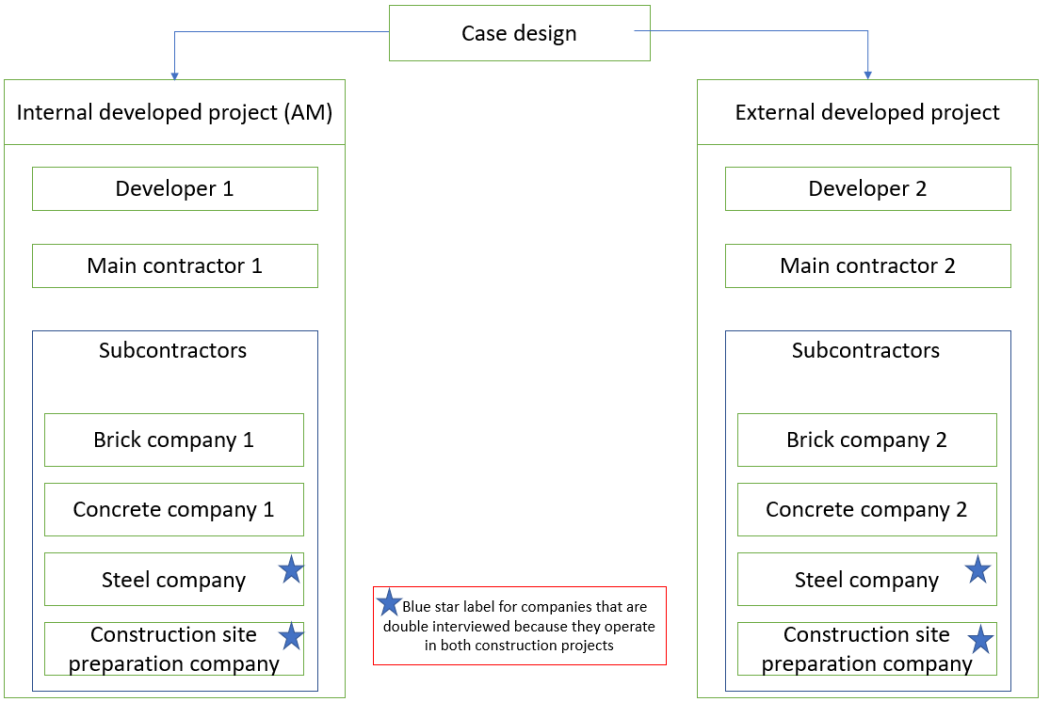


*Figure 5 Case design*

Given the sensitive information provided by the respondents in the interviews, the data is processed anonymously. This includes the choice to not specify job titles and company types when using quotations from the interviews. Data supporting the findings of this study are available on request from this thesis' author. The interview data is not publicly available due to company sensitive information on the one hand, and interview data from the research participants that might be traced back to individuals. With the aim to enhance this study's credibility, the interpretation of the interview data was scrutinized by internal peer review and by the daily supervisor.

### 3.3 Method of analysis

First, the interviews were fully transcribed. The data obtained from the interviews was processed in four stages according to Bryman's qualitative analysis method (Bryman & Burgess, 2002). To begin with, the whole (transcribed) texts of the twelve interviews were read at once. Any notes were written down to ensure that the major themes can be uncovered. Subsequently, the second stage consists of rereading the texts. Mark text while reading and identify coding labels. These labels will assist in interpreting the collected data. The third stage comprises coding the data and reviewing the labels and codes. For coding, the coding tool ATLAS.ti was used. The coding consists of closed and open codes. The closed codes were formulated based on the identified barriers and drivers in the literature review (Chapter 2). The open codes emerge during the coding process. When a quotation cannot be placed in the closed code section, a new code will be created. For both open and closed coding, the same six categories as described in section 3.2.2 are used to classify the barriers and drivers. An overview of this can be found in Figure 6. The data from the program ATLAS.ti is described in Chapter 4. In the fourth and final stage, general theoretical ideas have to be related to the data and coded text. In this stage, theory and data are integrated and explained, meaning the data is interpreted. This is described in Chapter 5.

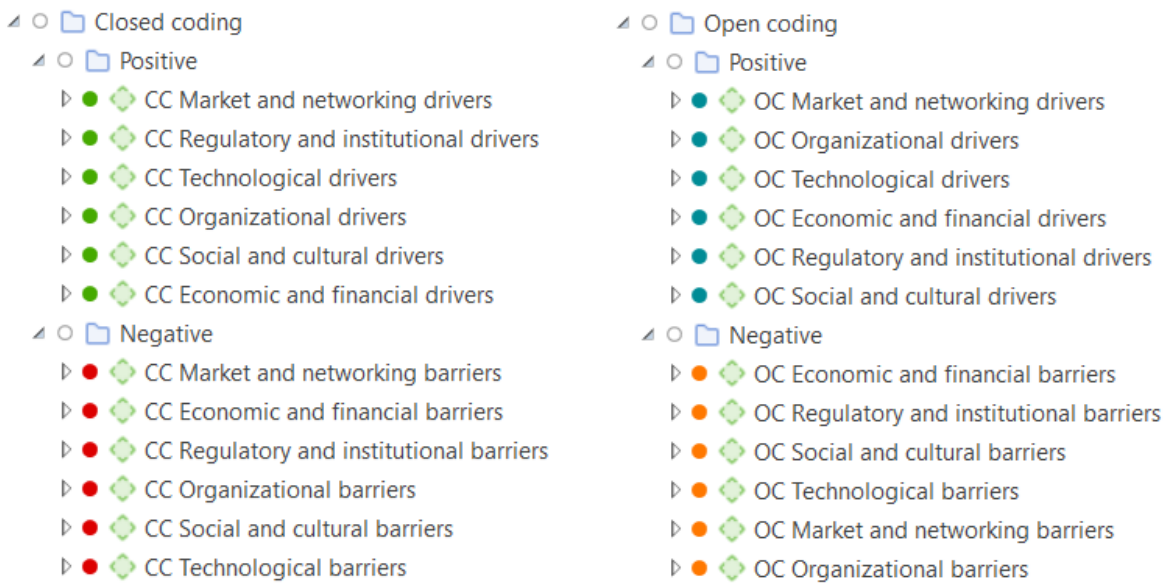


*Figure 6 Closed and open coding categories*

Based on the results of the codes, it was analyzed how often barriers and drivers were mentioned by different actor types (subcontractors, main contractors and property developers) as well as how often they emerged based on whether the housing project was developed by an internal or external property developer. From there, top 10 barriers and top 10 drivers were formulated for every actor type and project type (internal or external property developer) and subsequently explained by illustrative quotes from the interviews. From these top 10 lists, comparisons could be made, which provided insights into the most important or most encountered barriers and drivers in the collaboration between the actors as well as possible differences between them.

Additionally, a selection of barriers and a selection of drivers was formulated that were not mentioned often enough to be incorporated into the top 10 lists. In these two selections, barriers and drivers were highlighted, because they seem to be of meaningful influence on the collaboration and sustainability processes in housing construction projects. This is partially based on the author's interpretation of the results. Triangulation was applied to enhance validity and credibility (Shenton, 2004). On the one hand, these selections of barriers and drivers were frequently reviewed and discussed with academic supervisors, thereby increasing the level of objectivity that this interpretation carries. On the other hand, multiple sources on a topic or situation can be consulted for the purpose of gaining a broad understanding of the research subject from multiple perspectives. This was done by interviewing multiple respondents that represented different actor types in the housing construction supply chain.

Data saturation is a good indicator of the credibility and validity of research results in qualitative analysis. In this study, data saturation was accomplished after the majority of interview data was processed, resulting in remarkable trends that did not change when more interviews were coded. Noteworthy to mention is that the increasing saturation rate occurred alongside the observation that during the coding process, fewer open codes were added as the coding process progressed, as is illustrated in Figure 7.

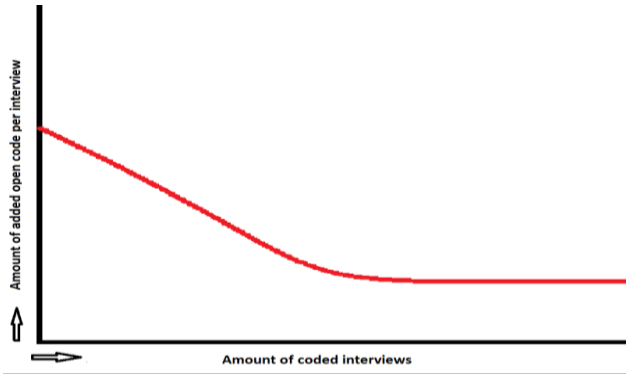


*Figure 7 Data saturation*

## 3.4 Case description

BAM is a Dutch construction and (property) development company that works in several construction industries worldwide, i.e. utility construction, residential buildings, infrastructure, as well as a division that specializes in developing digital design, digital engineering, industrialization, circularity, modularity, energy transition and new technologies. This study is focused on BAM Residential, the company segment that "unites the activities for environmental and property development, residential construction, sustainability and renovation of existing residences" (BAM).

### 3.4.1 BAM's sustainability goals

BAM has established objectives to become more sustainable as the desire to alter the conventional construction methods. To keep global temperature increases below 1.5 degrees Celsius, one of its objectives is to cut back on carbon emissions. When compared to 2015, the initial target was to cut Scope 1 and Scope 2 carbon emissions by 50 percent before 2030. However, BAM already decreased their Scope 1 and Scope 2 carbon emission levels by 44 percent in 2021. Based on these accomplishments, new targets were set, which can be found in Figure 8. The first objective is to cut Scope 1 and Scope 2 carbon emissions by 50 percent in 2023 instead of 2030 (compared to 2015), followed by a second objective to reduce the same emissions by 80 percent in 2026 (compared to 2015). BAM implemented several measures to reach these sustainability objectives, e.g. the electricity that is used will be entirely made of green electricity, BAM only leases completely electric vehicles and equipment, and hydrotreated vegetable oil will be used as biofuel in place of regular diesel.

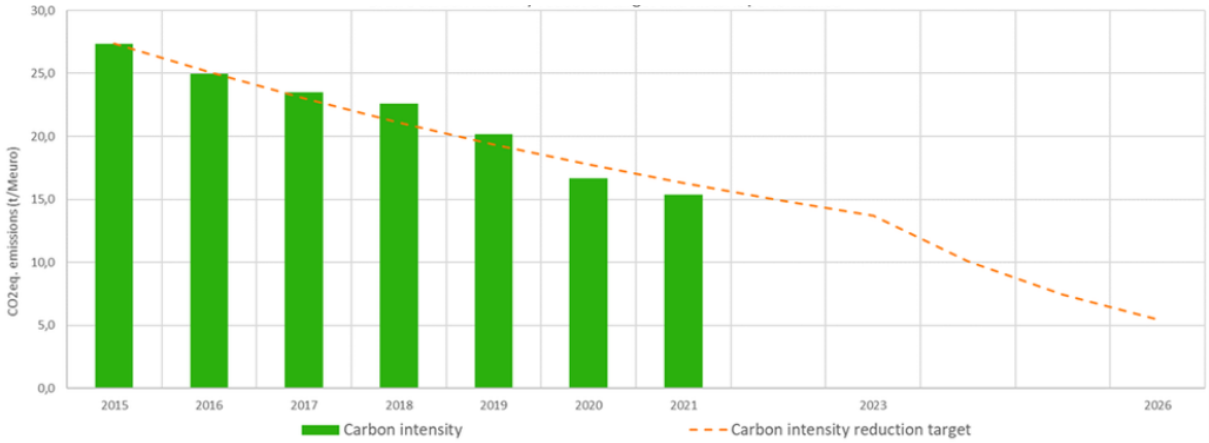


*Figure 8 BAM's carbon intensity reduction target and historic performance (BAM, 2023)*

There are solutions to lower the emission in Scope 3 both upstream and downstream. For upstream activities, the use of building materials such as concrete and steel is primarily responsible for $CO_2$ emissions. The consumption of energy from BAM-supplied products is closely related to the release of

$CO_2$ downstream. BAM decided to raise its goals for reducing Scope 3 emissions in 2022: in contrast to 2019, the new objective is to cut $CO_2$ by 50 percent before 2030. BAM's influence on decreasing $CO_2$ for Scope 3 is considered to be more difficult than reducing $CO_2$ of Scope 1 and Scope 2, since Scope 3 can be seen as a value or supply chain where products gain value after each successive activity.

This indicates that the chain is made up of numerous subcontractors, all of which have quite different supply chains and goods. Each subcontractor must add their own component to the final product as part of the chain, therefore they are all required to use their own way. This decision has the effect of passing responsibility for construction practices and therefore emissions to the subcontractor when the contract is outsourced. It is crucial to exert more control over the subcontractor when it comes to building practices and decision-making in order to lower the emissions of scope 3. All subcontractors are responsible for adding their enrichment to the product which automatically means that each subcontractor chooses their own method. Therefore, when the contract is outsourced, the responsibility for construction methods and thereby the produced emissions is transferred to the subcontractor. It is crucial to exert more control over the subcontractor when it comes to building practices and decision-making in order to lower the emissions of Scope 3.

BAM is focusing on strengthening the value chain in order to cut Scope 3's $CO_2$ emissions by 50 percent before 2030. This is accomplished through expanding the stakeholder's participation in the construction-related decarbonization process. Before 2023, the BAM hopes to provide the client low-carbon construction designs, even if the client does not explicitly request it. A few examples of how the BAM has helped stakeholders get more involved:

- Increase the level of collaboration among concrete suppliers to create concrete that emits less $CO_2$ emissions.
- Increase industry collaboration so that more durable recycled steel is used in construction.
- Forming organizations to advocate for more durable ways in construction technology.
- Offering integrated design solutions to lower the $CO_2$ footprint of construction materials.
- The establishment of performance targets for the construction industry.

With the decarbonization goals set for the future, the end goal is clearly illustrated. How to get there, however, is not immediately apparent. The contractor might not reduce the amount of emissions produced during construction for a variety of reasons. In order to achieve the sustainability goals of the main contractor, it is crucial to conduct research on the barriers and drivers that influence the collaboration between the main contractor, subcontractor(s) and property developer(s), which is what this study aims to do.

# Chapter 4: Results

This chapter presents the results obtained from the case study research, which consisted of semi-structured interviews. In this chapter, barriers and drivers will be uncovered that occur for the housing construction industry. Thereby, this chapter aims to answer the third subquestion: *What are the barriers and drivers that the most influential actors in the housing construction industry encounter in their collaboration to implement sustainability in the housing construction industry's supply chain?*

The results in this chapter are discussed per actor type (subcontractor, main contractor and property developer). Each section will elaborate on the aggregated barriers and drivers, after which they will be illustrated with quotes from the interviews. First, the top 10 most mentioned barriers for each actor is presented. It shows the category to which the barrier belongs, how often it has been mentioned in total and whether it is included in the closed or open coding. Subsequently, this will be followed by a section that highlights a number of barriers that were not coded enough to get to the top 10. These barriers, however, hold great potential to hinder the process towards sustainability and are hence important to mention. Next, an analysis follows that explores the differences and similarities in the barrier categories between the different actors, as well as differences and similarities between the supply chains for internally and externally developed housing projects. Subsequently, the same outline will follow for the drivers for sustainability. Furthermore, an analysis is presented on the co-occurrence of barrier and driver categories, followed by a synthesis in which the findings for each category will be integrated and interpreted.

## 4.1 Barriers

To understand what barriers hinder the implementation process of sustainability in the supply chain during the construction of houses the most an overview is given. This overview contains the most important barriers that possibly slow down the development of a sustainable supply chain. These barriers are from the actors perspective and are sorted based on the number of occurrences in the interviews.

### 4.1.1 Top 10 barriers per actor type

#### *4.1.1.1 Subcontractors*

*Table 6 Top 10 barriers - Subcontractors*

| | Barrier | Category | Frequency in interviews | Closed /Open |
|---|---|---|---|---|
| **1.** | Lack of money to invest (investment is too high) | Economic and financial barriers | 16 | CC |
| **2.** | Sustainable products are seen as more expensive at the moment | Economic and financial barriers | 13 | OC |
| **3.** | The price for a sustainable product is too high to implement it | Economic and financial barriers | 12 | OC |
| **4.** | Lack of worker's training on sustainable operations | Social and cultural barriers | 10 | CC |
| **5.** | Institutions slow down sustainability | Regulatory and institutional barriers | 10 | OC |

| | | | | |
|---|---|---|---|---|
| **6.** | Not enough knowledge about sustainable implementations and the possibilities | Technological barriers | 9 | OC |
| **7.** | People and companies do not like to change to other methods like sustainable methods because change results in resistance | Social and cultural barriers | 9 | OC |
| **8.** | The institutional rules are not clear enough and multi interpretable | Regulatory and institutional barriers | 9 | OC |
| **9.** | Lack of government support system | Regulatory and institutional barriers | 9 | CC |
| **10.** | There are not enough rules and regulations set by the government | Regulatory and institutional barriers | 8 | CC |

From the interviews conducted among subcontractors, the number one barrier that was mentioned the most was the **lack of money to invest in sustainability**. From a subcontractor point of view, it could mean that the subcontracting party wants to innovate and become more sustainable, but there are no funds available to them to meet their sustainability needs. From the interviews, the following emerged: *"I think it is a general tendency, so not only for BAM. I think that BAM wants to be at the forefront, but when the costs of a project increases by several tons, then BAM also says that does not fit us. The margin is not that large and if you work more sustainably and that causes more risks, then they don't do it."* Additionally, another subcontracting party stated that "*Those are only a few big guys, you know. All the other parties think: that costs us money and that's not something we are going to do."*

The lack of knowledge also weighs in on another barrier in the pursuit of sustainability: the fact that **sustainable choices in materials and products are perceived as more expensive** and are hence not regarded as the right choice to use in the housing project. This barrier focuses mainly on the way of thinking about sustainable choices – even before products are compared and a product choice is made, people tend to prefer non-sustainable choices, since their mental image about sustainable choices leans towards that it is too expensive. Measures are taken in this regard, but this is still a barrier: *"(…) but with BAM you notice that they really look at the price, because it is ten percent more expensive. But ten percent is the maximum. Oftentimes, it is not even that more expensive. But it is more the process around it: new products, processing parties that ask more [money]. They think that they will have delays because it is new, although you can pave more and quicker there than with regular bricks. There are a lot of impediments you need to take care of, that is why you need to have a couple of trial projects to showcase it."*

Additionally, **the price of sustainable products is too high to implement these.** Logically, when prices for sustainable choices are compared to the regular non-sustainable choice, the amount of profit a subcontractors makes from the housing project decreases notably. One respondent for example states *"(…) to show to BAM that we have sustainable devices in storage that we can employ. It is, however, not realistic to work with such machinery with the current price rate. (…) It is twice as expensive."*

Moreover, subcontracting parties indicated that some people from different **worker's** in the project (no particular actor type, can be for all actors) **lack training on sustainable operations** and **do not have knowledge about technical possibilities** (barriers 4 and 6)**.** This, in turn, hinders them from taking serious steps towards sustainable steps, due to lacking knowledge about how to get there and what steps can be taken towards this goal. One of the subcontractors illustrated this: *"(…) Most people [in the project] know how a brick is manufactured, but there are also a lot of people that are not aware of*

*this. (…) There is a lot of ignorance. Sometimes you visit a project and you explain "we don't have this brick at the moment". [Imitating question from the other party:] But you can make that brick easily, right? But that takes two to three weeks."*

Furthermore, **institutions are slowing down sustainable improvements that subcontractors may want to implement**. A clear example is provided by one of the respondents: *"(…) within the municipality of Amsterdam has so many departments, and someone has a say in it as well as another. It is a long bureaucratic hassle. I think they should act more."*

From a psychological point of view, it was identified that there is resistance to change. The barrier that is mentioned by the subcontracting companies was **people and companies do not like to change to other methods like sustainable methods because change results in resistance.** As one respondent says*: "There are stonemasons, for example, who want to work in ways they are used to. This Ecobrick is smaller. A stonemason is used to the old stone and knows how to work with it. They know how much mortar is needed to lay that brick properly and now they have to think [about new ways and products]. (...) it is a routine and that routine is interrupted, with which they struggle a lot."* Another respondent said: *"Regarding the time it takes for a housing project to move from one phase to the next: because of waiting time for concrete to harden and the way people are not thinking about lessening this time. They do it traditionally this way, so they do it now as well."*

Subcontractors struggle with **unclear institutional rules that are multi interpretable**. This hinders them from knowing what (not) to do. Unclear rules can cause loss of valuable time, because things have to be figured out before implementation. On the other hand, it might cause financial damages because of fines or adjustments in the project in a later phase than necessary. One respondent states: *"I still find it all quite unclear. (…) As the government, you simply have to ensure that there is a clear policy in place providing directions on where we need to go in the future. It's just too unclear at the moment."* Another interviewee added: "*Well, I think they should at least make the boundaries clearer. And now it sometimes still relies too much on interpretation."*

Elaborating on institutional factors, a **lack of a proper government support system** also constitutes a barrier experienced by subcontractors. One subcontractor indicates they need a step by step approach, instead of a system where new rules and laws have to be implemented all at once: "*Just step by step and not all at once, not "this is it and you must abide by it". Even if you are going to build in nature. (…) It will soon be shut down in court. You have already moved the first pillar, so your costs continue. But you are not allowed to build, so there is no income either. If you don't deliver within a certain timeframe, you get fines."* A second respondent added: "*Everything is implemented simultaneously. Diesel should be minimized, emissions on construction, nitrogen and CO2. You name it. Everything comes at once. (…) You cannot expect that everyone in the Netherlands will drive in electric cars in two years, that's not possible. Not financially and cars are too expensive, but also labor, batteries, charging, generating electricity. It won't work. And I think that the government should take normal steps in this regard and not too quickly."*

Lastly, subcontractors add to the previous two barriers that **there are not enough rules and regulations set by the government**. One respondent elaborated on how the government does not take every aspect or consequence into account when setting the rules: *"Well, the government is only concerned with emissions, if you look at the farmers and us too, the housing industry. We are short of housing, but we have to stop [building] everything. I don't think the government knows much about it. They have a short-term perspective, they see emissions so they have to do something with that."*

#### *4.1.1.2 Main contractor*

*Table 7 Top 10 barriers - Main contractor*

| | Barrier | Category | Frequency in interviews | Closed /Open |
|---|---|---|---|---|
| **1.** | Lack of money to invest (investment is too high) | Economic and financial barriers | 8 | CC |
| **2.** | The price for a sustainable product is too high to implement it | Economic and financial barriers | 7 | OC |
| **3.** | Insufficient environmental competencies | Regulatory and institutional barriers | 4 | CC |
| **4.** | There are not enough rules and regulations set by the government | Regulatory and institutional barriers | 4 | CC |
| **5.** | Sustainable houses become too expensive and therefore won't be sold | Economic and financial barriers | 4 | OC |
| **6.** | The institutional rules are not clear enough and multi-interpretable | Regulatory and institutional barriers | 4 | OC |
| **7.** | Not enough knowledge about sustainable implementations and the possibilities | Technological barriers | 4 | OC |
| **8.** | The negative way in which messages and rules are communicated | Regulatory and institutional barriers | 3 | OC |
| **9.** | Sustainable products can be seen as more expensive | Economic and financial barriers | 3 | OC |
| **10.** | Lack of understanding and knowledge on SSCM among organizations in the chain | Market and networking barriers | 2 | CC |

From the interviews conducted among project managers of the main contractor, the number one barrier that was mentioned the most was the **lack of money to invest in sustainability (investment is too high).** This could mean that although the main contractor has enough money to invest in sustainability, the subcontractor lacks money to invest in sustainability. As one respondent illustrates: *"(…) I don't see it. (…) Because the same machines are still driving around. Yes, it's not going fast enough, but I can't check their financial capacity to see how their financing works. (...) What room is there for implementing technology? Lots of room, until it gets too expensive. We dare to make that investment, but it will not get through the deal, because you're going to raise your price.''*

Another barrier that was frequently mentioned by the project managers of the main contractor was **the price for a sustainable product is too high to implement it.** Oftentimes, financial decisions are made by property developers, meaning that main contractors have to adapt to the budget and design choices made by property developers. Therefore, main contractors have to make choices and cut back on sustainable solutions, because there is no sufficient budget. From the interviews, the following emerged: *"In my surroundings, I still see a race to the bottom, everything is about prices. It's still the case that the lowest bidder wins. (...) There are 100 points to earn [in a tender], but 80 points are about the price. And then there are all those things that they would like to have besides that and you only get 20 percent for that. So what does a tender team do? It removes all those expensive sustainable things.*"

In addition, another respondent said "*Another example is this wooden house. We would like to apply biobased insulation, but you can go very far with that. You can do a biobased facade finish in the base, but currently, biobased materials are more expensive than our traditional materials. So you can be idealistic and make such a house completely perfect from a sustainability point of view, but that is not yet financially feasible at the moment. So, I think that's a big barrier to acceleration*."

Additionally, **insufficient environmental competencies** from the regulatory and institutional perspective were frequently mentioned as barriers. When the institutions are not competent enough to understand what to regulate, it can result in insufficient outcomes. This emerged during the interview. "*We have, for example, with the development of the wooden house, where you want to calculate the noise and vibrations and then they have to fall back on German standards.(...) we have little experience with it, we actually (...) have to fall back on those standards. But we do not live and work in Germany, if you need to apply for a permit, it needs to be done here. So, keys and stuff are here. But if a municipality cannot check it, because the law and regulations are not yet clear or are not there at all, then you are blocked in a technical way*."

There are **not enough rules and regulations set by the government**, which also constitutes a barrier. From the main contractor point of view it could mean that the rules that are implemented by the government, do not cover the spectrum which is needed to make clear the way of sustainability. From the interviews, the following emerged; "*We are just not familiar with those new materials and the government, they are somewhat reluctant to do so. An example of this is stone strips. In our new concept, mineral stone strips are used as a basic finish. (...) Those mineral stone strips are a product that we are not yet very familiar with in the Netherlands. (…) But that is also from a piece of law and regulations. If we can just calculate it very clearly and demonstrate that it suffices. And the municipality has the same calculations, that they know they can check it in the same way, well then that matches. But apart from the municipality, would you also see more if more was invested in that technology? I think it's just a matter of time.*"

The barrier **sustainable houses become too expensive and therefore won't be sold** indicates that working under the assumption that houses will not be sold because of the price of sustainability also hinders progress in sustainability in the housing construction industry. From the interviews, it emerged for example that "*You use a green roof. You can fill it with solar panels. You can put infiltration crates in the garden. The storage room with a green roof. The extension with a green roof. You can insulate it very well. There are always costs involved. So that will be an incredible expense? Yes, and of course that's kind of the balance. We prefer to have the most sustainable house. Well, we should all be able to afford it.(…) Money has to be made. Otherwise we cannot proceed. Yes. If we later have a whole new concept with a beautiful wooden house and everyone thinks it's too expensive, so will the client and the housing consumer. Yes, of course it stops.*"

Main contracting representatives also indicated that **the institutional rules are not clear enough and multi-interpretable** was a barrier they encountered. This could mean that the main contractor has difficulties when it comes to interpreting the rules that are set by the government in the correct way. This can be the result of rules that are not clear enough and multi interpretable. From the interviews, the following emerged: "*Much clearer and simpler. Those nitrogen rules, well. First, it keeps moving over time. Then it starts again in June. Then again in January and then again later. They don't even know themselves. And if the makers don't already know, how should we implement it in the right way? Time is money. If we have to go through a permit process and we don't know exactly what to submit and the municipality doesn't know exactly how to check it, then we get questions and the process might take longer. And that's a shame.*"

Subsequently, another barrier mentioned was **not enough knowledge about sustainable implementations and the possibilities.** The following emerged from the interviews: "*Look, technically we are just not used to those materials. Just a lot of calculations and tests, which still have to be done. And that just takes time and money. To know how to optimize that? Yes. An easy example is a retaining wall. They have tested 100,000 variants with strut walls and they have also been certified. But if you suddenly start putting bio based insulation in it or another type of plasterboard. Before someone says, this is fire resistant for 30 to 60 minutes, it must be tested. Sound is just very difficult with biobased materials and a different structure. So you just have to test that very well.*" Another interviewee from the main contractor stated that he/she has the idea that parties such as property developers and the government do not have enough knowledge about the consequences of sustainable implementation in houses. This can result in the main contractor having to implement products in the house without knowing how to do this correctly. This conclusion draws on the following quote: "*But they don't quite understand what that means. And the moment you start working that out and you come up with; yes but you ask this. I notice that from the response and the non-answer. It's so much. And a lot is placed with people, which is a very specialized thing. Yes that can happen, yes. I don't feel like they're deliberately pushing that off. But I think there is a misunderstanding about how much we can solve as a contractor.*"

**The negative way in which messages and rules are communicated** is another barrier that was mentioned a few times by the main contractor. The respondent indicates the way a government gives a message about becoming more sustainable. At this moment, the government has a negative tendency when it comes to giving this message. It could mean that the main contractor feels a shift in becoming more sustainable which is associated in a negative way because it feels forced. The following emerged from the interviews: "*I don't like the method by which good things are brought into the world. So I mean regulation, lawsuit, okay. Then something arises. I don't like that route. (…) Because I think it's very negative and I also think it's a very negative image of sustainability. (…) Everyone is taken and that at some point everyone gets the realization. And how do you do that marketing wise or psychologically? That's a very complicated one. But therein lies the crux. Yes, now it's more about fines, right? Yes you will be punished. A high energy bill, construction stops. It's a big mess now. (...) Well, I don't find it very convincing, the way they are selling the story right now. They also really sell it as we have to. That's not good enough. So that could be better. Explain why we have to and why it is a good plan. It's a bit of a victim role. And finger pointing. So don't be in the position of having to. But I want the government to be in the position that I think this is what I'm responsible for, and I believe that, and I'll explain to you why. I would consider that a huge improvement. Yes, now everyone here has a scapegoat, I think. They all say, we have to. (…) But not like: why are we doing this? At the moment it is certainly not a hindrance. But it is more or less shoved down our throats. But you can't get around that. The way of communication is extremely important."* Another respondent added: *"More and more. But it is done in a very negative way: we have to. (...) How can you avoid something if you really have to? That just has to do with the way of communicating. It's purely about communication."*

Furthermore, **sustainable products are seen as more expensive**. Therefore, they may not be considered as the right choice to use in the housing project. This barrier focuses mainly on the way of thinking about sustainable choices – even before products are compared and a product choice is made, people tend to prefer non-sustainable choices, since their mental image about sustainable choices leans towards that it is too expensive. As one respondent illustrates: *"What you see is the reaction from different actors, which is: why is sustainability always more expensive? (...) It is not always more expensive, but a little development also plays a role. When we look at clickbrick, for example. We are a party that relies upon volumes. The higher the volume, the cheaper it is. We put clickbrick on the market for a competitive price compared to the production costs of the brick."*

Lastly, main contractors named **a lack of understanding and knowledge on SSCM among organizations in the chain** as an important barrier. Lacking the proper knowledge about sustainability could hinder to the extent that the pursuit of sustainability in the construction housing industry gets stalled. The following emerged from one of the interviews: "*Well, I don't notice that the penny has dropped everywhere yet. And that has mainly to do with the fact that it is terribly in the way.*"

#### *4.1.1.3 Property developers*

*Table 8 Top 10 barriers - Property developers*

| | Barrier | Category | Frequency in interviews | Closed /Open |
|---|---|---|---|---|
| **1.** | Uncertainties in the market competition | Economic and financial barriers | 9 | CC |
| **2.** | The companies that process the new product in the house are afraid to work with the product because they do not know it and so they raise the price because of risk | Economic and financial barriers | 9 | OC |
| **3.** | Lack of money to invest (investment is too high) | Economic and financial barriers | 9 | CC |
| **4.** | Not enough knowledge about sustainable implementations and the possibilities | Technological barriers | 6 | OC |
| **5.** | Wide communication gap (market/networking) | Market and networking barriers | 5 | CC |
| **6.** | Lack of understanding and knowledge on SSCM among organizations in the chain | Market and networking barriers | 4 | CC |
| **7.** | No responsibility by involved parties | Market and networking barriers | 4 | CC |
| **8.** | Sustainable houses become too expensive and therefore won't be sold | Economic and financial barriers | 4 | OC |
| **9.** | The price for a sustainable product is too high to implement it | Economic and financial barriers | 3 | OC |
| **10.** | Resistance of suppliers to implement certain clean technology practices for products, production and logistics | Market and networking barriers | 3 | CC |

The barrier that was mentioned the most among property developers was **uncertainties in the market competition.** This implies that they are not sure how to navigate in the market between their competitors when it comes to the (amount of) implementation of new and sustainable products. As one respondent illustrated: "*Which insulation material, which this, which that? But it doesn't work that way because when you ask that question, they say yes, yes, yes, difficult, we just do rockwool because we know that it works. But no, we just want to go one step further. And so, you now see that there is a certain lack of knowledge, they don't know what's for sale, they don't dare to give guarantees or the*

*risk is added up in the price*." Another quote adds to the same barrier: "*You must therefore have a business case and that is under pressure from a financial point of view. I think that's a big barrier. Especially now that the housing market is experiencing a bit of a correction. So I see that as a risk. That we are now actually making headway with circular construction and the energy transition, as well as other sustainability topics. But you still have to get that margin in a down market, so it definitely plays a big role.*"

Adding to the previous barrier, it was often said that **the companies that process the new product in the house, are afraid to work with the product because they do not know it and so they raise the price because of risk.** From the interviews emerged the following: "*BAM has a lot of parties where they buy a lot, so where they know the price and they know the quality. It's where they know if something works, (...) that you can guarantee it. But that is also a barrier to getting started with examples of innovative biobased products, just to name a few.*" Another respondent added: *"As soon as your work planners come up with something that is very risky because it has not been tried or tested before, they will get a slap on the wrist like how did you manage to do this. That's not how we do it here. So you just see from the risk that there is also a brake on that.*"

The third most frequently mentioned barrier by the property developers was **a lack of money to invest (investment is too high).** As illustrated in an interview: *"We have a partnership with [company name] and we have asked a number of contractors to become partners as well. And BAM is a partner too. [Name] endorses the program as a company, but if I ask can we upload our project? Then we have to pay money for that. Does that not depend on whether we have made the right arrangements in advance? They are right about that, because the project has been running for a number of years. And when we started, we didn't yet have that partnership or that desire. Gradually that wish came true and I believe so they say. And now we have to incur costs again to do this with the model. And I indicate, I am a partner of [company name], you are a partner of [company name] so they should be able to find each other because apparently you also have that ambition and objectives. But if I get the answer from the client, yes it costs us 15,000 euros, here's an invoice.''*

Moreover, **not having enough knowledge about sustainable implementations and the possibilities** presents a barrier to property developers. It is possible that they experience a lack of knowledge in the purchase division of the main contractor and in work preparation. This can result in that sustainable products will not be purchased even when these products are available: "*There is a knowledge gap in all purchasing and work preparation aspects in the field of circular materials and sustainable materials. I think that's the core. And at project level you notice that, because we ask the question: can we also purchase or use more sustainable alternatives? Is it all for sale and how you can build more sustainably, that you actually lack that knowledge there? (…) Especially the knowledge about sustainable materials. But I mean, those people don't have enough knowledge, so they are unable to buy those sustainable things.*"

**Lack of understanding and knowledge on SSCM among organizations in the chain** also emerged a number of times from the property developer's perspective. Lacking knowledge on how to become more sustainable and what steps to take towards implementing SSCM is also stipulated in one of the interviews: "*I almost feel like people don't know that. (…) And then they go to a new project and suddenly sustainability comes along and then they start thinking we have never done this before. So people who actually only learn when they encounter it in a project and because projects often take years. It's quite okay, it goes with a bit of hurdles and bumps.*"

Property developers also pointed to a **wide communication gap (market/networking)** as an important barrier. If there is little to no communication between actors, this may result in some sustainable

alternatives not being implemented. In this case, one actor does not indicate that they would like to have a certain sustainable product implemented. The following was said in one of the interviews: "*And some of those fellow producers also have sustainable alternatives where we yes. If it is not requested, then we will not purchase and apply it ourselves."* Another quote from a respondent: *"And how has the policy of both parties been designed with regard to sustainability? You both want to, but the real connection and kind of sustainability pact has not really been closed yet? No."*

Property developers mentioned sometimes **no responsibility by involved parties.** This can result in sustainability goals of companies within the chain differ too much and hence alignment is lacking in order to effectively pursue increased sustainability. From the interviews the following emerged: "*What you see when your ambition in scope 3 and your measures are too far apart, then it really starts to create friction. Then it will hit projects, and that has happened.*" In this case, the respondent aimed at a situation between BAM and the property developer. The procurement department and property developer were in conflict, since the property developer was working from a sustainable perspective, whereas procurement was not.

Property developers also worry about how **sustainable houses become too expensive and therefore won't be sold**: *"Financially, what role does money play in sustainability? Yes, you must therefore have a business case and that is under pressure from a financial perspective. I think that's a bigger barrier. Especially now that the housing market is experiencing a bit of a correction. So, I see that as a risk: that we are now actually making headway with circular construction and the energy transition, as well as other sustainability topics. But you still have to get that margin in a down market, so it definitely plays a big role."*

The property developers also mentioned a couple of times how **the price for a sustainable product is too high to implement it.** The consequence, then, can be that the overall price of the house will rise to a value that is too high. Then the house won't get sold. The following emerged during one of the interviews: "*The challenge is that new techniques, because they still have a somewhat small scale, are often simply more expensive and that is where the barrier is again. So the costs, you see that with wood construction, constructions. I have not had a single project where it is cheaper than traditional concrete construction. So there are still more costs on that wood construction. But also installation technology. You also have energy installations. There are super-efficient, few rotating parts, a super nice system. But it is simply more expensive than an air-to-water heat pump and even more expensive than a ground source heat pump. So if you know that your revenues are limited, so have a maximum, then at some point you can no longer lose. You also have to have a certain margin and achieve a certain return to be a somewhat economically sustainable company.*"

The last barrier mentioned by property developers is the **resistance of suppliers to implement certain clean technology practices for products, production and logistics.** This hinders the implementation process of sustainability in the housing construction industry. An illustration: *"If they say, we are now going to use the click brick for the first time, then they find that really exciting. Are you saying that there is actually a kind of fear within BAM like they don't dare with a new material because we don't know how it will turn out? Yes, because if it comes loose from the facade or whatever after a few years, okay then from the warranty you have to repair it as building. And the margins are just pretty low in construction, so your profit margin goes away. So there is little room for this kind of thing.*"

#### 4.1.2 Miscellaneous barriers outside the top 10

In the previous section, barriers have been discussed based on how often they were identified by respondents. During the interviews, however, some barriers that were mentioned may not have been named often enough to get to the top 10, but seem to be of major influence on the collaboration and

sustainability processes in housing construction projects. They are therefore important to mention here as well.

#### *4.2.1.1 Closed coding*

*Technological barrier: Inappropriate technology to improve*

This is a barrier describing situations where, for example, a sustainable machine is not able to operate like an original machine. The machine falls short technically. An example provided by a respondent: "*One of our largest cranes is a hybrid. (…) I don't think it can lift well if it's really heavy material."*

*Market and networking barrier: Bad collaboration between companies*

When good collaboration is lacking between actors, it can hinder the efforts to become more sustainable overall. This may occur when actors are not collaborating in the first phase(s) of the project, preventing an optimal sustainable implementation. One respondent illustrated: *"What you generally see is in the collaboration, design and also discussing what is possible and what is not. So this is extremely important, especially with architects. What really went wrong with some projects is that the architect came up with a design in advance."*

*Social and cultural barrier: Stay with traditional technology and culture*

This occurs when companies and their employees do not want to change towards a more sustainable way of working, because they want to stick to the traditional way of working. This attitude of favoring traditional technology and culture can hinder the way to become more sustainable. One respondent elaborated: "*For example, [company name] does a lot for BAM with bricklaying. That company just says: yes, I'm not going to do that click brick, I have nothing to do with that. The owner just says that he has nothing to do with that click brick. They indicate that it does not suit them at the moment."*

#### *4.1.2.2 Open coding*

*Economic and financial barrier: The costs of failures are too high which prevents taking care of sustainability*

During the construction of houses, there are costs of failure. Generally, sustainable construction products are more expensive than the traditional construction products. With low margins, it becomes difficult to implement sustainable products, because the costs of failure take up too much space in the budget. An example of this barrier can be found in one of the interviews: "*Because sustainability generally costs more. Contractors, what do they earn per year? They are happy when they have 1.5 to 2 percent left. That is actually shockingly low. All you have to do is do this and you're left with nothing. (…) Well, I think there are a lot of costs of failure in construction. I sometimes stand on such a construction and then I think how on earth is it possible?"*

*Economic and financial barrier: When a construction method is sustainable, but takes too much time*

Sometimes, the implementation of a sustainable construction method can take more time compared to the traditional construction method. Construction companies want to construct as quickly as possible to complete the job. Since time is often a very important factor, this can prevent the use of a sustainable construction method. As one respondent illustrates: "T*hen he chooses that he wants to go faster with this cement. It is sensitive to heat and it is cold outside in the Netherlands so this cement hardens very slowly. But then you put more cement in it and have a heavier, faster hydrating process, that is precisely the most polluting component of the concrete, that cement part, what we put in it to allow that contractor to build and continue building faster. Actually, he should just let his concrete rest*

*for a week longer and only then continue to build. But that costs money. (…) You want to save time and therefore it must contain a certain amount. We don't mind if they wait longer, but the contractor does not want to wait and therefore asks for a heavier concrete class with more emissions."*

*Economic and financial barrier: Before you can make sustainable purchases, you have to wait until the investment costs of your previous machines have been depreciated*

When machinery is purchased, it always implies an investment. To make this investment profitable, the machines have to operate till they are depreciated, which takes time. When traditional (not sustainable) machinery is not depreciated yet, it may be too soon to commit to another investment. This hinders a swift implementation of sustainable machinery. As one respondent stated: "*Look, the cranes and shovel companies have made significant investments in heavy equipment. And that stuff is far from being depreciated. And replacing it will not go very quickly."*

*Economic and financial barrier: Wanting to sell a product and not showing the advantages of it clearly to the customer*

When a company has a sustainable product to sell to a potential buyer, it is important to clearly show the function and benefit of the product. If this is not done properly, the sustainable product may not be purchased, which can be a barrier in reducing emissions when constructing a house. An example from one of the interviews: "*I think that is also the biggest challenge for us as an organization. If you want to sell something, you also have to show what the advantage is. Look, we do a lot about it, but we can't always show the value of the product. Now we have built a number of test houses and now we can show BAM why the product works well. Then, you can show what the product produces."*

*Technological barrier: An electric network to supply electricity for the sustainable electric machines is not present and this hinders the implementation of sustainable machines on the construction site*

When an electrical network is insufficiently present on a construction site, electrical machinery cannot be supplied with (sufficient) electricity either. This can be a barrier when it comes to reducing emissions when constructing houses. This is described in the following quotation: *"Back to the Netherlands with the electrical infrastructure. They cannot handle this amount of power consumption. We can fill a construction site here, fill every construction site in the Netherlands with electric cranes, but then you consume an entire village worth of electrical energy."*

*Market and networking barrier: Resistance of main contractor to invest together with subcontractor in sustainable products or measurements*

What can hinder the sustainability process is the unwillingness of involved parties to jointly invest in more sustainable products and better measurement equipment. As one respondent stated; "*Well, I have one more current example. Not from BAM because I want to enter project [project name]. And that is an ambition that has only gradually emerged. So I asked the question: we want that in [company name] and something has to be done in those models. Then I get an invoice from BAM for what it costs. So then there is no intrinsic wish from BAM."*

*Market and networking barrier: Aesthetic preferences block the integration of sustainable products*

When an architect has a specific vision on the aesthetic image of a house, it implies consequences on the sustainability during construction. When the architect prefers a less sustainable product over a more sustainable product and draws a design, the other parties must comply, which can obstruct the reduction of emissions when constructing a house. This was illustrated by one respondent: "*Click brick is also a system with limitations. What you see with architects who ultimately have to make a choice*

*and what is important: is it an aesthetic interest or is it a sustainable interest? And ultimately, a choice has to be made. Yet, you notice that there are architects who prefer to use a different color and therefore do not opt for the more sustainable option. And then, I say. The starting point is, these are just the basic colors and these are the design guidelines. You just have to take that into account if you just want to have a good sustainability project. They come up with frills that cannot be done with such a system, with what you can do with masonry, for example."... This barrier potentially occurs when certain actors in the construction chain know it is possible to use a sustainable product, but do not implement it. Therefore, it is important to inform other actors of the sustainable product. An example from one of the interviews: "Only in the end it also starts with the development and with the contractor wanting to use those products. That's why I have a lot of conversations with people within the [internal development] group. And also within your own club and then we discuss how we can ensure that we can get more and more sustainable solutions and sustainable products in our projects."*

*Market and networking barrier: Not implementing a durable product when it is possible*

This barrier potentially occurs when certain actors in the construction chain know it is possible to use a sustainable product, but do not implement it. Therefore, it is important to inform other actors of the sustainable product. An example from one of the interviews: *"Only in the end it also starts with the development and with the contractor wanting to use those products. That's why I have a lot of conversations with people within the [internal development] group. And also within your own club and then we discuss how we can ensure that we can get more and more sustainable solutions and sustainable products in our projects."*

*Market and networking barrier: Subcontractor gets involved in the project too late, so that useful expertise can no longer be used*

During the initial phase of a design, there is room for discussion about the implementation of certain products. When actors that have knowledge about sustainable products are excluded from this initial phase and are introduced in a later phase, there is less opportunity to implement sustainable products. An example from one of the interviews: "*At final design you are too late. So when you actually start buying that, you are too late. Because then the design is already too far. So you actually have to make sure that you already take that comaker's knowledge or what it is selling around preliminary design. And sometimes we do that before. Then we have tenders where you are very much challenged in terms of circular performance. Then you have to go into depth on these types of parts much earlier."*

*Market and networking barrier: Showing too little to another party that you want to become more sustainable as a company*

When a company has the image that it stands for sustainability, other parties want to work with them in a sustainable way. This facilitates the process for actors in the chain to become more sustainable. When a company does not make clear that they stand for sustainability, it can result in a less sustainable collaboration between partners because it was not clear. This barrier can hinder the construction chain in the process to become more sustainable. An example is given with the following quotation: "*It may be that we do too little to be seen and therefore do not show clearly enough that we want to be included in the sustainability process. We may not do enough with our marketing, for example."*

*Organizational barrier: Not clear for all company employees where to acquire the right information for them to work, produce or buy sustainable products*

In the organization, there are experts on specific processes or products. This is also the case for experts on sustainable products. Many of the employees of the company are not aware of the presence of this information in their organization when they want to implement a specific sustainable product. This can hinder the implementation process of sustainable products for the construction of houses because of the time loss or the unnecessary hiring of external experts. This excerpt illustrates this: "*I would like more centrality, (…) now I know that after a while. If I want to know this, then I have to go to construction and technology because someone is there and they are very handy at it. But for the other things I have to go to advice and engineering, because there is someone there who understands that. So that this is taken seriously and not so fragmented. Now you have to go to separate places everywhere for your questions. I miss that, yes."*

*Regulatory and institutional barrier: (Former) members of cement companies decide the norms about amount of cement in one $m^3$ concrete so that companies can make money*

When (former) members of the cement industry are part of the commission that defines norms for concrete strength, it forms a possible barrier in the pursuit of increased sustainability. Cement is one of the substances that determines concrete strength and is also responsible for $CO_2$ emissions. Less cement in concrete results in a reduction of these emissions. The norm for concrete strength defines a minimum amount of used cement in concrete in order to guarantee concrete strength. If higher amounts of cement are set in this norm, this results in higher emissions during concrete production. The amount of cement used in housing projects, however, can be lower without endangering the required concrete strength that ensures safe use of concrete. One respondent illustrated how (former) members of the cement industry take part in the norm setting commission: *"These entire standards, so to speak, are all concrete standards stating the amount of cement that must be in a cubic meter of concrete for a certain strength. There are all standard committees for that. But if you then find out who has been or are sitting on those standards committees, those are all people from the cement industry and from the sand and gravel industry."* From this, it can be deduced that interests from these former industry members may be twofold, meaning that they can somehow have a financial interest in determining the norms for the use of cement in concrete.

*Regulatory and institutional barrier: Laws and rules change too quickly, causing parties to not have enough time to properly adjust*

Another identified barrier is that sometimes, institutions change laws and other rules and want adhering parties to implement this too quickly. For multiple reasons, companies need sufficient time to implement these new laws and rules. When they do not get this needed time, they cannot keep up, putting them at risk of violating the law and becoming subject to high fines. One of the first focus areas that are compromised is sustainability. As one respondent explained: "*Well the regulations. Everything is coming together now. So diesel should minimize emissions on construction, nitrogen and $CO_2$. You name it. Everything comes at the same time. And that cannot be. You cannot expect that the whole of the Netherlands will drive electrically within two years. That's not possible. Not financially and the cars are too expensive, but also labor, batteries, and so on. Charging, generating electricity, you cannot get it anymore. I do think that the government should take normal steps in this regard and not too quickly."*

*Regulatory and institutional barrier: Not providing a clear explanation of subsidiary policy*

Subsidies can help to move companies to become more sustainable. These subsidies are defined by the government. It is a problem when it is not clear for companies what a specific subsidy entails and

in which situation they can claim it. Failing to know what subsidies a company can claim or how to claim it will result in less claims and therefore in less investments in sustainability. As one respondent said: "*So that subsidy all helps to get off to a good start, yes. (…) only those are redefined every year, the rules of the game of the subsidies and it is really a barrier.*"

*Social and cultural barrier: Laziness of people prevents good integration of sustainability on the construction site*

When employees do not feel responsible and do not take responsibility, it can be a barrier in the process in becoming more sustainable. The lack of knowing the results of one's actions can influence the behavior of a company in such a way it hinders sustainable progress. An example from one of the interviews: "*That one is too easy. Stuff is thrown together at the construction site while it is clearly stated what needs to be put in it. Then there are about ten containers on the construction site and then someone throws something like that into the container it doesn't belong in. Then you have a problem because such a container can then be disposed of as bulky waste.*"

### 4.1.3 Analysis of overall barrier categories in interviews based on actor type

Three actor types are subject to this case study: subcontractors, main contractors and property developers. In this section, the actor types will be compared based on how often they have mentioned barriers from the different categories. In Table 9, it can be found how often each barrier category has been mentioned per actor type. In determining the most important barrier categories, the amount of open and closed codes has been accumulated. Since there were more subcontractors interviewed, the sum of identified barriers differs from main contractors and property developers.

*Table 9 Frequency of mentioned barriers by subcontractors, property developers and main contractor*

| | Subcontractor | Property developer | Main contractor |
|---|---|---|---|
| CC Economic and financial barriers | 18 | 11 | 7 |
| CC Market and networking barriers | 20 | 15 | 4 |
| CC Organizational barriers | 10 | 3 | 1 |
| CC Regulatory and institutional barriers | 14 | 3 | 4 |
| CC Social and cultural barriers | 11 | 1 | 1 |
| CC Technological barriers | 8 | | 2 |
| OC Economic and financial barriers | 32 | 16 | 11 |
| OC Market and networking barriers | 19 | 9 | 1 |
| OC Organizational barriers | 2 | 2 | 1 |
| OC Regulatory and institutional barriers | 19 | 10 | 9 |
| OC Social and cultural barriers | 23 | 3 | 5 |
| OC Technological barriers | 17 | 9 | 5 |

Looking at the **subcontractors** in the housing construction chain, it stands out that the economic and financial barrier category is mentioned more often compared to other categories. Overall, the three most important barrier categories are economic and financial barriers (50), market and networking barriers (39), and social and cultural barriers (34). On the other hand, the organizational barrier category was mentioned less than all other categories (12).

When analyzing the **property development's** most mentioned barriers, two categories stand out. For one, this is the economic and financial barrier category (27), followed by the market and networking barrier (24). Subsequently, the two barrier categories that proved to be the least mentioned among property developers were technological barriers (9), organizational barriers (5) and social and cultural barriers (4). What stands out from the results, is that none of the previously defined barriers in the technological barrier category came up during the interviews. This indicates that none of the technological barrier category from the literature was found to be a barrier by any of the respondents.

For the **main contractors**, it was found that the most important barriers are economic and financial barriers (18) and regulatory and institutional barriers (13). Furthermore, the least mentioned barrier categories are market and networking barriers (5) and organizational barriers (2).

Comparing the overall results from the three actor types, it stands out that the most important barrier category is economic and financial barriers (95). Moreover, the organizational barrier proves to be the least referenced category (19).

#### 4.1.4 Analysis of overall barrier categories in interviews based on internally developed construction chain versus externally developed construction chain

The interviewed actors in the housing construction chain that participate in this case study were derived from two similar housing construction projects. There is, however, one important difference: one of the projects was developed by an external property developer (not BAM), whereas the second project was developed by BAM. This way, an analysis can be done to determine whether there are outstanding differences in the barriers encountered in the construction chain based on whether the project was developed internally or externally. In Table 10, it can be found how often each barrier category has been mentioned by the actors in the construction chain for the internally (indicated as AM) and externally developed projects. In determining the most important barrier categories, the amount of open and closed codes has been accumulated.

*Table 10 Frequency of mentioned barriers for internally and externally developed housing projects*

| | Internally developed | Externally developed |
|---|---|---|
| CC Economic and financial barriers | 25 | 16 |
| CC Market and networking barriers | 23 | 19 |
| CC Organizational barriers | 8 | 7 |
| CC Regulatory and institutional barriers | 12 | 16 |
| CC Social and cultural barriers | 10 | 5 |
| CC Technological barriers | 7 | 7 |
| OC Economic and financial barriers | 39 | 29 |
| OC Market and networking barriers | 21 | 10 |
| OC Organizational barriers | 4 | |
| OC Regulatory and institutional barriers | 23 | 23 |
| OC Social and cultural barriers | 21 | 11 |
| OC Technological barriers | 23 | 14 |

For the **internally developed project**, the most frequently mentioned barrier categories are economic and financial barriers (64) and market and networking barriers (44). On the other hand, organizational barriers (12) were identified less as a barrier category for the internally developed project.

Looking at the **externally developed project**, economic and financial barriers (45) and regulatory and institutional barriers (39) were identified as the two most important barrier categories. Additionally, organizational barriers (7) again proved to be the least referenced barrier category. What stands out from the results, is that none of the previously defined barriers in the organizational barrier category came up during the interviews. This indicates that none of the barriers within the organizational category from the literature was found to be a barrier by any of the respondents.

Furthermore, when comparing the barrier categories for both the internal and the external project, it was found that economic and financial barriers (109) is the most important category. Subsequently, organizational barriers (19) is the least mentioned barrier category by both parties.

## 4.2 Drivers

### 4.1.1 Top 10 drivers per actor type

#### *4.2.1.1 Subcontractors*

*Table 11 Top 10 drivers - Subcontractors*

| | Driver | Category | Frequency in interviews | Closed /Open |
|---|---|---|---|---|
| **1.** | Create an environmental collaboration between main and subcontractor | Market and networking drivers | 26 | CC |
| **2.** | A support system offered by the government with regulations and effective legislation | Regulatory and institutional drivers | 22 | CC |

| | | | | |
|---|---|---|---|---|
| **3.** | Legal requirements | Regulatory and institutional drivers | 17 | CC |
| **4.** | Commitment of the top management | Organizational drivers | 16 | CC |
| **5.** | Good communication on implementation of sustainable products between contractor and subcontractor and property developer | Market and networking drivers | 16 | OC |
| **6.** | Create awareness among involved parties | Market and networking drivers | 15 | CC |
| **7.** | Create a technology push | Technological drivers | 15 | CC |
| **8.** | Access to advanced technology for sustainable operations | Technological drivers | 14 | CC |
| **9.** | Develop collaboration agreements | Market and networking drivers | 14 | CC |
| **10.** | Tax incentives by the government | Regulatory and institutional drivers | 12 | CC |

The driver towards sustainability mentioned the most by subcontractors was to **create an environmental collaboration between the main contractor and the subcontractor**. This could be done in a number of ways, including stipulating sustainability in corporate cultures. As one respondent states: "*I think that both parties are very happy and very open to sustainability. So I think it is number one on the agenda in both corporate cultures.*" Another respondent explained: "*I think we have very good contact with BAM and that we can talk about everything. And that we know the right people within BAM to discuss things with and possibly realize them*." Another respondent said: *"It has nothing to do with your research, but there is something going on right now. A huge step forward and that is 100 percent collaboration and we are proud of that.*"

Besides environmental collaboration between them and the main contractors, subcontractors also point towards **a support system offered by the government with regulations and effective legislation**. One respondent said about this: "*Then you see that we can get a subsidy from the government for this. But that has only just been demonstrated with LCA [Life Cycle Analysis], so that is fairly new. But I think that in the future it will benefit us financially as a contractor. That will help us then. So it becomes more interesting. It is then rewarded to use this product because it is a circular product."* Furthermore, another respondent stated: *"I (…) mean the governments. I do not hope for pressure. But I know that [pressure] works, yes. Companies are being forced now, but I hope not. Because we all have to keep our jobs, but it must be subsidized. The companies that do their best should receive an advantage. That's a nice idea behind it.''*

Noteworthy is that the top three drivers for subcontractors concern enabling systems or cultures to enhance the pursuit for sustainability. The two formerly mentioned drivers are followed by a need for **legal requirements**. Following these are mandatory for a subcontractor to stay in business. It might not be an enabling factor per se, but not keeping up with legal requirements is necessary for a company to be able to keep working on housing projects. This is illustrated by a respondent that said "*You also*

*simply have to comply with the requirements and regulations that are set in order to still be a player in the future.*"

Concerning organizational drivers, the main driver is the **commitment of (top) management** to sustainability: "*When I say, let's think about making a hydrogen power station here as well, then we'll think about it. (…) Look, the first door on the left there. There is the first door of management. You walk in there and you talk to them, the door is always open*." Enabling and focusing on sustainability from (top) management is important to ensure that all suggestions to pursue sustainability may be discussed, clearing the way for subcontractors to think creatively and take responsibility when it comes to sustainable building.

The next driver that subcontractors identified is **good communication on the implementation of sustainable products between the main contractor, subcontractor(s) and property developers**. Since good communication and strong collaboration reinforce each other, this may enhance the pursuit of increased sustainability. In such an environment, good ideas may arise, which in turn may be implemented sooner. A respondent illustrated: "*That's why I have a lot of conversations with people within the [property developer] group and also within your own organization. Then we discuss how we can ensure that we can get more and more sustainable solutions and sustainable products in our projects.*" Another respondent added: "*If something new comes along and we can apply it to our current equipment, then yes. I can brainstorm well with BAM performers. Good ideas always.*"

**Creating awareness among involved parties** also constitutes an important driver for sustainability. This awareness aims at bringing more focus and attention towards sustainable options within all parties involved in housing construction projects. A respondent said: "*It is also requested more and more by the contractor. They want to build more sustainably, we want to be more sustainable. Then, we will also be included in what you can do and how we can do that together.*" Adding to this, another respondent states: "*We have a mission (…) to make it clear to the world that we are actually quite green. I think that, perhaps, we are one of the greenest power stations in the Netherlands.*"

From a technical perspective, **creating a technology push** is another identified driver: "*If you look at the new factory that we are going to convert to Ecobrick, there we will produce in a different way. We will be working there with a printing technique. This way, therefore, diminishes our gas use and emissions. And thanks to this new technology, we can provide better and more sustainable guarantees for the world.*" Moreover, another respondent said: "*We are also working on the concrete slabs to make them 40 percent lighter with less concrete. (…) We are currently developing that and we also work with that biodiesel. It is made from animal fats and vegetable oils. That makes biodiesel up to 90 percent better concerning emissions.*"

Adding to enabling factors is obtaining **access to advanced technology for sustainable operations**. Focusing on sustainability and enabling people to work towards this also includes making sure the right people have access to the necessary technology. Subcontracting parties indicate their interest in expanding their core business based on advanced technology: "*(…) They supply durable roof coverings for flat roofs. That is, for example, also a product that we have seen. Ultimately, you have to do something with that, too. We also do a lot now in solar panels and systems like that. So in the end, you can also see that we are expanding our core business.*"

**Developing collaboration agreements** is another factor driving the sustainability efforts forward: "*(…) in the consultations that are held (…), we are expected to adapt to and work towards a goal for two years from now.*" Illustrating this further, another respondent added: "*BAM triggers us to also invest in making those new adjustments to your concrete plant. That is, sometimes, co-financed by the contractor so that we can produce sustainably and not just make our own investments.*"

Lastly, subcontracting parties also look to the government for **tax incentives** to make sustainable solutions more attractive. A respondent explained: "*There is a frontrunner principle. The companies that adapt best to climate change are now being subsidized a bit and, well, those rules are being worked on. Those who do not cooperate are actually punished because they can no longer comply with the rules. So they are then going to follow those frontrunners. (…) If you don't participate in new developments, Rijkswaterstaat actually does not want anything to do with you.*" Tax incentives also make up for part of the additional costs that sustainable investments bear with them: "*If (…) you are going to work with certain electrical equipment, then it is something for companies like us to work with subsidies. You earn back the fact that you buy electrical machines and work with them.*"

#### *4.2.1.2 Main contractor*

*Table 12 Top 10 drivers - Main contractor*

| | **Driver** | **Category** | **Frequency in interviews** | **Closed /Open** |
|---|---|---|---|---|
| **1.** | Legal requirements | Regulatory and institutional drivers | 9 | CC |
| **2.** | Position sustainability in such a way it becomes popular so that people want to pay for it | Economic and financial drivers | 8 | OC |
| **3.** | Commitment of the top management | Organizational drivers | 7 | CC |
| **4.** | A support system offered by the government with regulations and effective legislation | Regulatory and institutional drivers | 6 | CC |
| **5.** | Integrating sustainable operations in proactive plans | Regulatory and institutional drivers | 6 | CC |
| **6.** | Create awareness among involved parties | Regulatory and institutional drivers | 5 | CC |
| **7.** | Public pressure (social/cultural) | Social and cultural drivers | 5 | CC |
| **8.** | Involvement of employees | Social and cultural drivers | 5 | CC |
| **9.** | Create a sustainable corporate culture | Organizational drivers | 4 | CC |
| **10.** | Bring sustainability as a positive change in the world and make people enthusiastic | Regulatory and institutional drivers | 4 | OC |

**Legal requirements** are not only a driving factor for subcontractors, main contractors also stipulate their importance. *"Well, the client wants to meet certain requirements. They get advice on that. (…) From the government, the market. So they all take things and they pile them on top of each other in a question. You must do that and you must comply."* Another interviewee added: *"And that's because those requirements are there contractually and we then pass them on to our co-makers. They then have to prove that they meet all the requirements in production. And quality marks and proof, too."*

From a marketing perspective, main contractors identified that **positioning sustainability in such a way that it becomes popular so that people want to pay for it** also improves sustainability efforts. One respondent said: *"You have to have the feeling that it is a nice advertisement. Like we radiate this. (…) If you create something in which society all wants to go in that direction, then companies will automatically want to jump in. And then, money is made again. (…) That Tesla is a brilliant thing. (…)They put down what is modern, it's what people want. There was no holding back."* Another respondent elaborated: *"It is even added value for companies. If a housing corporation says, we are going to build wooden houses, then you can put that in the newspaper. That you're working on that. You can also polish your image with it. So the time we're in right now is actually perfect in that sense. We are a bit late when you look at climate change, but that wooden house and those sustainability packages. If we offer it now, the market is ready and the money is there. So it ties in very nicely. I don't see much resistance. Actually not on any level."*

**Commitment from top management** is an important driver mentioned by main contractors. When top management does not deem sustainability important, it will be hard to maximize sustainability in housing projects. On the other hand, if top management commits itself to sustainability, projects can aim for higher sustainability standards. As one respondent explained: "*I think we have people who can get the mandate from someone, buyers or whatever. If a director says to a buyer: you have permission to close this deal at that work, yes then it will be arranged."* Adding to this, another respondent stated: *"You really have to go to [name of COO], for example. Those are not deals I can make. I can't just put 50,000 euros in an electric faucet."*

Additionally, main contractors see an important driver in **a support system offered by the government with regulations and effective legislation**. *"(…) Crucial. At this time. It has to be cranked up. Now every day on every screen I see that. (…) Yes that excludes a consequence, Lawsuits, regulations. (…) Well, you have to make it clear to people that you are doing a good thing and that it is important. (…) You must be able to explain it to each other."* Another interviewee explained the following: *"I just mean the governments. I hope not for pressure But I know that works yes. companies are being forced to now, but I hope not. because we all have to keep our jobs. But it must be subsidized. the companies that do their best should receive an advantage. That's a nice idea, yes."*

**Integrating sustainable operations in proactive plans.** When the government operates proactively, this can result in a behavioral change with regard to actors operating more sustainably. This may help the process of making the construction chain more sustainable. *"I think maybe you should start taxing the bad actors. When I look at it from our industry: concrete. A concrete house should simply be less attractive than the wooden house in the overall town. And I don't know if you have to subsidize the wooden house. I do not know. That incentive, eventually. The money eh, that you choose the wooden house because it is cheaper. That would just help a lot.*"

A driver that is implicitly incorporated in all drivers, is the need to **create awareness among involved parties**. Simply put: "*Well, you have to make it clear to people that you are doing a good thing and that it is important."*

**Public pressure** (from a social/cultural perspective) also nudges projects towards more sustainable solutions, main contractors argue. One respondent said: *"If you just look at the developments of those wooden houses. Here they hijacked the entire 7th floor of the building. There are people from all kinds of BAM departments. People are then asked if they want to participate in this [project of wooden houses]."* Another respondent added: *"But if you look at Scandinavian countries where there is now a kind of flying shame, then you have it on a personal level. (…) Look, we really don't do everything*

*perfectly, but we try to come by bike every now and then, and eat organic meat. I have a son, so we try to buy as many second hand toys for him as possible."*

Subsequently, **involving employees** in sustainability is perceived as a driver towards sustainability. One of the respondents stated: *"Seeing all those young designers in Eindhoven, they were all working with recycling and biobased products. You see a change there and that comes from this new generation, they see it. They think it is very important (...) and they won't know any better. That is of course a good foundation for the future."*

Besides public pressure, **creating a sustainable corporate culture** also pushes sustainability forward according to main contractors: "*Yes, it lights the fire. And then it also depends a bit on the club of people you have together, such as all kinds of circumstances and histories. Or that that can fuel that fire. And show vulnerability. Explain why you do things. Then there will be a response."* Another respondent added: *"Well, the fact that we have [name] as a product manager, we have created that function. Because sustainability is of course part of that colleague's job. That's already a lot, we didn't have that before. Now we have a new concept and the product manager who is on top of it, so we are really changing."*

Lastly, main contractors identified **bringing sustainability as a positive change in the world** and **making people enthusiastic** from regulatory and institutional actors as a driving factor in the pursuit of sustainability. As one respondent explained: *"Well you get to the point of no return at some point you know. You have to crank something up and the moment it goes over the hill, it starts rolling. And then it goes by itself. Then all the government has to do is make adjustments. Then you have to make a little bit of regulation so as not to let it go out of control. It must be focused. That is the role of the government."* Another respondent added: "*And now we do notice that clients [often the government for this actor], and certainly clients where you offer wooden homes, that they are willing to pay extra for that. So that makes it a bit easier for us as well."*

#### *4.2.1.3 Property developers*

*Table 13 Top 10 drivers - Property developers*

| | Driver | Category | Frequency in interviews | Closed /Open |
|---|---|---|---|---|
| **1.** | A support system offered by the government with regulations and effective legislation | Regulatory and institutional drivers | 11 | CC |
| **2.** | Create a sustainable corporate culture | Organizational drivers | 10 | CC |
| **3.** | Information sourcing about green technologies | Technological drivers | 10 | CC |
| **4.** | Create an environmental collaboration between main and subcontractor | Market and networking drivers | 9 | CC |
| **5.** | Develop collaboration agreements | Market and networking drivers | 9 | CC |
| **6.** | Commitment of the top management | Organizational drivers | 9 | CC |
| **7.** | Create a technology push | Technological drivers | 8 | CC |
| **8.** | Tax incentives by the government | Regulatory and institutional drivers | 7 | CC |
| **9.** | Knowledge of sustainability in the companies | Market and networking drivers | 7 | OC |
| **10.** | Create good measurement data | Technological drivers | 7 | CC |

A recurring driver among all actor types is **a support system offered by the government with regulations and effective legislation**. A property developer respondent elaborated: "(…) *And those grants, just look at electric driving. That was also with the addition [of taxable income for electric cars]. Also a nice example. The subsidy on heat pumps has also been withdrawn. It was there once before gas became the norm, but that subsidy really helped us with this. So that subsidy helps to get off to a good start, yes.*"

Property developers agree with main contractors that **creating a sustainable corporate culture** is an important driver towards sustainability. Culture encompasses a set of values, meaning that in this regard, sustainability is incorporated into the organization's culture. This can develop into standards that exceed the bare minimum for sustainable measures, as this respondent explained: "*We have goals that go beyond the minimum, so we enter our lower limit. Our lower limit for new projects is always higher than the Building Decree. And we have a dot on the horizon to go from energy neutral to a positive impact and there is commitment to that on all levels, also in decision-making.*" Another respondent added: "*Then we try to ensure that in terms of sustainability, we ask for more than is required by law. So we are ahead of the requirements when it comes to the reuse of materials, circularity, to name a few things."*

Moreover, property developers point towards **information sourcing about green technologies** in their pursuit of sustainability. One respondent elaborated: "*Well, actually, we focus very much on KPIs. So, for the contractor a KPI can be; the MPG or the Beng scores and to the co-makers to make that happen. That's what's behind it. But with energy we have a number of parties that we place in energy systems with which we also give substance to the energy concepts for that objective. So those co-makers are important both internally and externally. Also, the parties we work with from infrastructure, for example. We use this to work on mobility concepts and mobility plans, so we do have a nice collaboration there. Internally we have a number of co-makers and also externally. So a little more on the consultant side, but we are slowly shifting to the circular side and also more in the construction chain. Because we see that asking the question or submitting on KPIs is not enough to change construction, so to speak."* Another respondent said: "*No more, we are partners of [company name]. I don't know if you know this, but that's a platform that BAM is also a partner of, it is a platform where circular material use can be registered. So you can measure in a project how many renewable raw materials are in the parts of the project and to what extent that project either already consists of circular materials or can be reused after demolition of the project. So we do prescribe objectives for that in projects. We want to make that measurable and partially manage it."*

Coming from a property developer's perspective, it stands out that **creating an environmental collaboration between main contractor and subcontractor** is third in the top ten drivers. A respondent explained: "*I brought colleagues from [subcontractor] and from [main contractor] together and I called it a circular task force. And the director of [subcontractor], the chairman of the board of [main contractor] gave each other an assignment. From that we make a plan on how we can jointly put a kind of dot on the horizon regarding how we are going to tackle it."*

Additionally, **developing collaboration agreements** to work on projects and learn more about sustainable building solutions was a driver mentioned by property developers during the interviews. A respondent illustrated: "*But because we have done and designed many projects, we have knowledge and experience. You must have projects to gain that knowledge and experience in your team. So that's going well. Look, BAM constructors were trained in concrete construction and there is a lot of knowledge there. Well, they had to make the switch to working with wood construction. They get that because they work with us on projects, but they also do training courses that go very quickly. I just see that improving project by project. The knowledge about wood construction and how they do it. So that goes on the [property developers] side and also on the [subcontractor name] side and BAM. So that triangle again, yes.*" Another respondent added: "*And that is now starting to grow towards each other again. Yes, and what has been crucial is that BAM developed that strategy together and that is super strong. So I think that's a very important precondition. That you are all on the same page.*"

Another driver that is recurring is the **commitment of top management**. When asked about narrowing gaps, a respondent explained: "*So you have to make sure that the things you encounter at project level, then you are talking about culture and collaboration, that you are on the same page between the departments. They say: "we want to go this way together.*" Another respondent said: "*Look, internally, that space is there. (…) If you provide motivation. So if you want to do something extra, you can motivate it and it may sometimes cost money and time.*"

Property developers also identify the need to **create a technology push** when pursuing sustainability: "*Previously, we have also put a wooden building on the green village with [university name], for example. So that kind of collaboration with students to test things is something we do a lot. Also from [property developers] we work quite a lot with universities. So I think that's very valuable, it can be educational for students, for the universities. Sustainability is just becoming increasingly important because that is simply the future.*"

Another driver identified by the property developers is the push that **tax incentives by the government** can create: "*Innovation grants or name innovation projects where you need to make less profit. (…) That is really an important driver. The fact that there is an environmental performance on buildings.(…) They are really crucial.''*

Furthermore, property developers indicated that **knowledge of sustainability in their companies** is an important driver. One respondent pointed out: "*That is actually getting better now. So that knowledge sharing at development level is actually going quite well. And the next step, I think, is that we train all colleagues within BAM in this much more and make it more known that [subcontractor name] has a lot of knowledge about this."*

Finally, **creating good measurement data** is an important driver to take into account in the pursuit of sustainability: *"Because you should actually know that [sustainability] about every product. Then you also know how sustainable it is and then you also know: maybe we should choose an alternative.*" Another respondent added: "*We are in a technical field. So that [sustainability measurements] is super important. And you can see it on all sides, from digitization to production techniques of new materials to installation technology. You can see on all sides that sustainability depends on technological developments. For me, technological development also means moving from concrete construction to a timber construction system, for example. You simply need new production methods and different knowledge for that*."

### 4.2.2 Miscellaneous drivers outside the top 10

In the previous section, drivers have been discussed based on how often they were identified by respondents. During the interviews, however, some drivers that were mentioned may not have been named often enough to get to the top 10, but seem to be of major influence on the collaboration and sustainability processes in housing construction projects. They are therefore important to mention here as well.

#### *4.2.2.1 Closed coding*

*Economic and financial driver: Create a market pull*

It is important for companies to continuously innovate to remain financially healthy. Since sustainability is becoming increasingly important, companies can benefit from investing in the field of sustainability. Therefore, challenging the market is a driver in the process of making the housing construction more sustainable. As one respondent explained: *"What they really want is to challenge the market. Just look at what is possible. (...) Because you will do anything to get the money, since you have to stay alive. You are not a philanthropic institution. Yes, to be able to recruit a location, you just have to have a super sustainable plan these days, and that is a driver to innovate and to continue with it."*

*Market and networking driver: Develop infrastructural support and facilities for sustainable operations*

It can be facilitating to have actors offer each other a helping hand to operate in more sustainable ways. This way, the collaboration can be improved in such a way that the construction chain becomes more sustainable. This is illustrated in one of the interviews: *"But with this biodiesel, that is a nice move. Then, BAM will come into contact with us. BAM will call and ask if we are interested in biodiesel. So that is how it is handled, even though biodiesel is more expensive."*

*Social and cultural driver: Create a sustainable corporate culture*

Incorporating sustainability in a company's identity and culture will help to uphold sustainable standards in the process of constructing houses in a more sustainable way. By incorporating this, the company is already steering itself to operate more sustainably, and therefore needs less guidance by governmental regulations. They are ahead of the rest of the market, which can be deemed a driver, especially when regulations are enforced on a short term, which can cause trouble for other companies that are not focused on sustainability. As stated in one of the interviews: *"We have goals that go beyond the minimum, so we enter our lower limit. Our lower limit for new projects is always higher than the Building Decree. And we have a dot on the horizon to go from energy neutral to a positive impact and there is commitment to that on all levels, also in decision-making."*

*Social and cultural driver: Involving the employees*

When employees in the company are actively involved in sustainability, they provide the company with innovative ideas that can subsequently be implemented to increase sustainability. These employees see opportunities on another level in their day to day work, providing different insights compared to when sustainability is only pursued from top level management. One respondent explained how a young employee can impact the working processes with their ideas: *"We have a boy here with a technical talent, who also likes doing it. So, if there is something new, we now also have that [talent and ideas] within our company systems. Either administratively or for processing. So, those are things that ensure innovation. If there are any ideas, it will be arranged immediately."*

#### *4.2.2.2 Open coding*

*Economic and financial driver: Financial advantage will support the integration of sustainability*

Money is often a good motivation for companies to change. An example where increased prices caused changes is when there was an energy crisis in the Netherlands (2022). Overall, the amount of gas used during the year decreased significantly since the price per $m^3$ increased quickly in a short amount of time. The amount of electric cars in the Netherlands increased simultaneously, since the price for electricity was lower. One respondent was very clear about the general relation between prices and the need/want for change: *"Yes, unless there is a financial advantage. Then, people tend to do something about it."*

*Economic and financial driver: Financial penalties when company not sustainable enough*

To ensure that people adhere to the rules, they get fined when rules are broken. One potential driver with regard to sustainability is to fine them when they do not operate in a sustainable way. A respondent explained how people and companies should be held accountable for not complying with sustainability rules: *"Then, you would have to impose fines for that. Then you can say, okay, you pay for this container yourself, because you have been throwing that waste into it."*

*Economic and financial driver: Share financial burdens together*

Operating sustainably on a regular basis increases a company's financial burden. Sharing this burden with other actors in the construction chain can compel organizations to choose more often for sustainable options. *"Do you also want to invest in this? Yes, the transport will change, so it will also have a different price tag. That's one thing for sure. but we are open to that too."*

*Economic and financial driver: When you want to sell a product, show clearly what the advantages are to the customer*

When a company sells sustainable products, it is important to make clear what the product is about and what its benefits are. This facilitates the chain to implement more sustainable products for the construction of houses. In the housing construction industry, it is not always possible to show certain products or implementations, because they are too big. One respondent illustrated the need to show certain products, although it costs more money to prove the benefits: *"If you want to sell something, you also have to show what the advantage is. Look, we do a lot about it, but we cannot always show the value of the product. Now, we have built a number of test houses and we can show BAM why the product works so well. This way, you can show what the product produces. And when things pay off, people tend to listen to you more quickly and make decisions sooner."*

*Market and networking driver: Being sustainable is good for the company name*

Showcasing that a company operates sustainable attracts other companies that seek to cooperate. Having a sustainable name in the market benefits both the company and the rest of the construction chain, as this respondent elaborated: *"Principles are very important, because they have to comply with certain rules and so do we ourselves. And the better we are, say, on the map as a sustainable company, the better (...) our business operations are."*

*Market and networking drivers: Clear policy on which sustainable alternatives can be used*

When it is clear to a company how sustainable alternatives can best be applied, it results in more sustainability. Having a protocol on how sustainable alternatives can best be implemented can stimulate sustainability, since people do not have to go through the same thinking processes again. This results in faster implementation processes during the construction of houses. An example from one of the interviews: *"Policy about alternative choices to conventional sustainable alternatives that you don't continuously reinvent the wheel."*

*Market and networking driver: Contract a sustainable architect for housing projects*

When a sustainable architect is hired to make the design, the focus on sustainability will increase. This step will facilitate the process towards sustainability in building houses. One respondent illustrated this well: *"And we really take sustainability into account when selecting architects. It depends on the project how important it is, but it is certainly an important task for [name] to do this well."*

*Market and networking diver: Get rid of partners that do not want to work sustainable*

When an actor in the construction chain does not want to work sustainably, it prevents progress when it comes to sustainability. It can therefore have a stimulating effect on sustainability efforts when people say goodbye to companies that do not want to operate sustainably. When the interviewer asked whether it would be a good idea to discharge partners that do not want to cooperate, a respondent answered: *"Yes, that could definitely be an option. Yes, definitely. Because if you want to participate in that story, you really have to commit."*

*Market and networking driver: Knowledge about sustainable procurement*

When a purchaser understands the skill of buying sustainable products, it results in the implementation and use of more sustainable products in housing projects. This will help make the process of constructing houses more sustainable. One respondent asked and answered their own question: *"So what is needed to become more sustainable in this case? Knowledge about sustainable procurement."*

*Market and networking driver: Main contractor communicates with subcontractors and property developers and shares their information*

In the construction chain, the main contractor stands in the middle of the developer and the subcontractors. All parties have valuable information about sustainable applications. It is facilitating the sustainability process when the main contractor communicates well with both parties in the chain and shares all the applicable sustainable information. One interview showed: *"I feel that maybe two more partners can add something. Those are the co-makers who then come into contact with BAM. Do you see the point in that? Because then they will receive product information that they can pass on to me again."*

*Market and networking driver: Parties talk about integration of sustainable products in the preliminary phase*

It is important to get together at the beginning of a project so that each party in the chain is able to contribute to sustainability. This also applies to parties in the construction chain such as the property developer, main contractor and subcontractor. If there is consultation in the initial phase, this facilitates the implementation of sustainable products in the construction of houses. When this conversation takes place during the final design, there is not a lot of room left to make different product choices. Getting everyone on the same page in this regard was also stipulated by one of the respondents: *"I think the best thing would be that you are even more of a co-creator by talking to each other much earlier and visiting each other. Then you can just rule out a lot of things. Then you can just cost a lot of time, energy. Then everyone is on the same page."*

*Market and networking driver: The property developer is the starting point for the implementation of sustainability*

The property developer often has a large share in designing the house that needs to be constructed. Therefore, it encourages the process of sustainability when the property developer makes a design that is focused on implementing as many sustainable options as possible. A lot of $CO_2$ emissions are the result of design choices. One respondent illustrated how important it is to have the right actor make the most sustainable choices: *"BAM wants it [sustainability], but then it has to be taken into account in the beginning. And that, in turn, lies with the property developer."*

*Organizational driver: Educate staff to reuse sustainable methods*

A driver for sustainability is training employees that work with sustainable products and methods. Training them on how to use these products and methods will also help them focus to think of ways that they can reuse them. As one respondent illustrated: *"They also have their own training school and they simply say, I think it's a fantastic product. They say, I'm just going to train a group of people in this. So the people who are now going into training at that company no longer learn the traditional trade of bricklaying, but learn the trade of dry stacking with click bricks. Then you have a whole perspective. They were also not trained with the old trade as a bricklayer, but with dry stacking. So the focus there is more on the long term."*

*Organizational driver: Use young employees that have innovative thoughts which will result in new ways of thinking*

Youth is the future, as some people say. This is also true for transitioning the construction process of houses towards a more sustainable approach. Young employees in a company can facilitate this since they often bring new perspectives on old ways of working. An example from the interviews: *"For example, I went to the Dutch design week over a year ago. And all those young designers there from*

*Eindhoven. They were all concerned with recycling and biobased products. So you just see a cover and that actually just comes from the new generation. They see that. They think that's very important. And I found that there. They don't know any better. And yes, that is of course a good basis for the future."*

*Regulatory and institutional driver: Provide incentives for sustainable products*

Incentivizing companies to become more sustainable by providing bonus points or other incentives is another driver. It helps to encourage companies to implement more sustainable products, as one respondent explained: *"That already exists now. So on those large tenders, we look at who does the best sustainability and then you get points for that. At the end of the construction you can prove that you have also achieved that, so you have to set feasible rules and at the end it is checked whether you have complied with them and then you will receive a subsidy."*

*Regulatory and institutional driver: Long term vision of the government*

A long-term vision of the government clearly indicates what can be expected concerning the implementation process of sustainability in the construction chain. This way, companies in the chain can adapt so that they become more sustainable in a smooth manner. One respondent stated: *"Yes you just need a longer term. A government should actually have a ten year plan. Then you know where you stand."*

*Social and cultural driver: Feeling and being responsible facilitates the integration of sustainability*

When people are made responsible for certain things, they will behave differently (more accountable) with regard to making the construction chain more sustainable. The feeling of responsibility that employees have will therefore have a facilitating effect when it comes to the process of becoming more sustainable. An example from one of the interviews: *"Well, because we [the employees] see ourselves as a driver of sustainable developments. And (...) because of our scale, we are convinced that we can also move the market in a certain positive direction. And then you're actually talking about the fact that we feel responsible for that as major property developers."*

*Technological driver: Create a central point or person that helps to find the right information to be more sustainable*

When people in a company need expertise on a specific subject, it is important they know where to find this expertise. This also applies when it comes to expertise in sustainable products. It is therefore important that employees can be referred to a sustainability expert via a central information point. As stated in one of the interviews: *"Well, (...) that we have a good point of contact. That we have good knowledge within BAM. That we probably already have it, only the central help desk. The general practitioner who refers you and also knows where that is missing. (...) Maybe they are already there, but he's not in the spotlight. If there is a general practitioner, we would like to know who it is and where to go if we have a question. I also recently had a new tender. Suddenly I was shown such a complete climate scan. Fantastic, I didn't know this existed and I didn't know we could do this."*

*Technological driver: An electric network for electric machines on the construction site*

Before sustainable construction machinery can be used, it is important that the infrastructure that makes durable construction possible has been realized. A sustainable electrical infrastructure enabling these machines will stimulate the process of constructing houses more sustainably. One respondent elaborated: *"Imagine being able to charge your electric car at the construction site. (...) Then you need fast chargers."*

*Technological driver: Produce in a prefabricated way so that transport flows are reduced*

Prefabricated products reduce production processes and time on a construction site. Prefabrication is more effective, which ultimately means fewer transports have to take place. This reduces harmful emissions such as $CO_2$ and nitrogen. A statement from one of the interviews: *"We are going to prefabricate it, so it is factory made. The factory is new and fully automated. There are a lot of solar panels on the roof, so we can produce very sustainably. It is prefabricated, so we can also make our transport more efficient. The largest part comes from that factory on the truck to the construction site and then we assemble it in a day. So you also have much fewer transport flows."*

*Technological driver: Slower construction process when working with concrete*

In the construction chain, a lot of work is done with concrete. Cement is used to harden and give strength to concrete, but this is an important ingredient that causes a lot of emissions. Less cement in concrete will not only result in fewer emissions, but also in a slower hardening process. It therefore follows that taking more time for concrete to harden in the construction processes means fewer emissions will be emitted. To limit the time loss, further construction can take place using temporary support structures. This means that less cement needs to be used, resulting in a more sustainable construction of a house. Illustrative to this argument is the following excerpt from one of the interviews: *"They want too fast. (...) There are rules in place for how much cement should be in there at least and we try to sit on that minimum. But nowadays, that is actually a thorn in our competitor's and our sides. Customers want to build faster and also now during the winter. Blast furnace cement is not the fastest cement, so now in this winter, they are going to ask for an addition [of cement] and yes, that is Portland cement as an addition. We tell our crown that they should actually build more slowly, but that time is money, so that is partly in the way of sustainability. (...) The sooner that concrete is hard, the sooner they can continue to build. There is a cost but also a negative aspect for sustainability. (...) Slower building (...) would be better and in any case, worldwide they are now trying to make those cement riveting shares in all kinds of cement types, because you have so many species to reduce it with all the consequences of it all hardening more slowly."*

*Technological driver: Create a scientific approach in consultation with a technological university*

Science is always at the forefront when it comes to innovative inventions. This also applies to sustainability. It is therefore important for companies to collaborate with technical universities to help them in the pursuit of sustainability in the construction chain. As one respondent explained: *"We have also previously put a wooden building on the green village with TU Delft, for example. That kind of collaboration with students to test things is something we do a lot. Also from [company name], we work quite a lot with universities. I think that is very valuable. It can be educational for students, for universities. Sustainability is just becoming more and more important, because that is simply the future."*

### 4.2.3 Analysis of overall driver categories in interviews based on actor type

Three actor types are subject to this case study: subcontractors, main contractors and property developers. In this section, the actor types will be compared based on how often they have mentioned drivers from the different categories. In Table 14, it can be found how often each driver category has been mentioned per actor type. In determining the most important driver categories, the amount of open and closed codes has been accumulated. Since there were more subcontractors interviewed, the sum of identified drivers differs from main contractors and property developers.

*Table 14 Frequency of mentioned drivers by subcontractors, property developers and main contractor*

| | Subcontractor | Property developer | Main contractor |
|---|---|---|---|
| CC Economic and financial drivers | 22 | 3 | 2 |
| CC Market and networking drivers | 41 | 12 | 7 |
| CC Organizational drivers | 21 | 12 | 9 |
| CC Regulatory and institutional drivers | 32 | 12 | 13 |
| CC Social and cultural drivers | 14 | 7 | 8 |
| CC Technological drivers | 30 | 11 | 3 |
| OC Economic and financial drivers | 20 | 6 | 13 |
| OC Market and networking drivers | 44 | 33 | 11 |
| OC Organizational drivers | 15 | 10 | 18 |
| OC Regulatory and institutional drivers | 20 | 6 | 11 |
| OC Social and cultural drivers | 15 | 9 | 5 |
| OC Technological drivers | 22 | 9 | 8 |

Looking at the **subcontractors** in the housing construction chain, it stands out that market and networking drivers (85) are mentioned more often compared to other categories. Additionally, regulatory and institutional drivers (52), as well as technological drivers (52) were deemed important driver categories by subcontractors. On the other hand, social and cultural drivers (29) were mentioned the least.

When analyzing the **property developers'** most mentioned drivers, one category stands out. Market and networking drivers (45) are the most important drivers in the pursuit of sustainability from the property developer's perspective. Less important in this regard are economic and financial drivers (9) as well as social and cultural drivers (16).

For the **main contractors**, it was found that the most important sustainability drivers are organizational drivers (27) and regulatory and institutional drivers (24). Furthermore, the least mentioned driver categories are social and cultural drivers (12) and technological drivers (11).

Comparing the overall results from the three actor types, it stands out that there is not one driver category the most important to all three actor types. For subcontractors and property developers, however, there is an overlap when looking at the market and networking drivers (130 without main contractor). Although there is not one most important driver category, there is a common least important driver category: social and cultural drivers (58).

### 4.2.4 Analysis of overall driver categories in interviews based on internally developed construction chain versus externally developed construction chain

The interviewed actors in the housing construction chain that participate in this case study were derived from two similar housing construction projects. There is, however, one important difference: one of the projects was developed by an external property developer (not BAM), whereas the second project was developed by BAM. This way, an analysis can be done to determine whether there are outstanding differences in the drivers encountered in the construction chain based on whether the project was developed internally or externally. In Table 15, it can be found how often each driver category has been mentioned by the actors in the construction chain for the internally (indicated as

AM) and externally developed projects. In determining the most important driver categories, the amount of open and closed codes has been accumulated.

*Table 15 Frequency of mentioned drivers for internally and externally developed housing projects*

| | Internally developed | Externally developed |
|---|---|---|
| CC Economic and financial drivers | 17 | 16 |
| CC Market and networking drivers | 38 | 36 |
| CC Organizational drivers | 29 | 18 |
| CC Regulatory and institutional drivers | 33 | 31 |
| CC Social and cultural drivers | 18 | 19 |
| CC Technological drivers | 34 | 18 |
| OC Economic and financial drivers | 24 | 21 |
| OC Market and networking drivers | 57 | 47 |
| OC Organizational drivers | 36 | 10 |
| OC Regulatory and institutional drivers | 21 | 22 |
| OC Social and cultural drivers | 18 | 19 |
| OC Technological drivers | 28 | 24 |

For the **internally developed project**, the most frequently mentioned driver categories are market and networking drivers (95), organizational drivers (65) and technological drivers (62). On the other hand, social and cultural drivers (36) and economic and financial drivers (41) were identified less as a driver category for the internally developed project.

Looking at the **externally developed project**, market and networking drivers (83) and regulatory and institutional drivers (53) were identified as the two most important driver categories. Additionally, organizational drivers (28) and social and cultural drivers (38) proved to be the least referenced driver categories.

Furthermore, when comparing the driver categories for both the internal and the external project, it was found that market and networking drivers (178) is the most important category. Subsequently, social and cultural drivers (74) is the least mentioned driver category by both parties.

### 4.3 Co-occurrence of barrier and driver categories

During the coding phase, quotes were assigned one or more codes. This section aims to analyze potential overlap and co-occurrence of the categories. When categories are mentioned often in close proximity to other categories, this could provide insights into which categories relate to each other. It could indicate that barriers and/or drivers potentially enhance each other or, on the contrary, are conflicting with each other somehow. Co-occurrence can happen in different combinations:

1. Barrier and barrier
2. Barrier and driver
3. Driver and driver

Furthermore, it is interesting to see possible differences between closed codes (CC) and open codes (OC) in the co-occurrence analysis. This could provide insights into any relationship between barriers and drivers that were also found in other industries (as described in the literature review) on the one

hand, and barriers and drivers that were found in this study specific to the construction chain on the other hand. Therefore, the following comparisons have been conducted in the following section:

1. CC co-occurring with CC
2. CC co-occurring with OC
3. OC co-occurring with OC

**CC co-occurring with CC**

In Table 16, one can find how often CC barrier and driver categories co-occur with other CC barrier and driver categories. Four category combinations stand out, meaning they are co-occurring often:

1. Organizational drivers - Social and cultural drivers (9)
2. Market and networking drivers - Social and cultural drivers (8)
3. Market and networking drivers - Organizational drivers (6)
4. Economic and financial drivers - Technological drivers (6)

It stands out that social and cultural drivers were the least mentioned driver category for each actor type, yet this category is found as the most co-occurring category in combination with organizational drivers (9) as well as market and networking drivers (8). This could mean that social and cultural drivers could potentially support or even accelerate the increase of sustainability in the housing construction sector when they are employed jointly with other categories. Further research into this correlation could provide insights into this observation.

*Table 16 Co-occurrence table closed code - closed code*

| | CC Econ... | CC Econ... | CC Mark... | CC Mark... | CC Orga... | CC Orga... | CC Regu... | CC Regu... | CC Socia... | CC Socia... | CC Tech... | CC Tech... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CC Economic and financial barriers | | 1 | 2 | 1 | 3 | | 1 | 1 | | | 5 | 1 |
| CC Economic and financial drivers | 1 | | 1 | 5 | | 3 | | 4 | | 4 | 1 | 6 |
| CC Market and networking barriers | 2 | 1 | | | 2 | | 1 | 1 | 5 | | | |
| CC Market and networking drivers | 1 | 5 | | | | 6 | | 5 | 1 | 8 | 1 | 5 |
| CC Organizational barriers | 3 | | 2 | | | 1 | 1 | | 4 | | 1 | |
| CC Organizational drivers | | 3 | | 6 | 1 | | | 3 | | 9 | | 2 |
| CC Regulatory and institutional barriers | 1 | | 1 | | 1 | | | 4 | | | 1 | |
| CC Regulatory and institutional drivers | 1 | 4 | 1 | 5 | | 3 | 4 | | | | | 2 |
| CC Social and cultural barriers | | | 5 | 1 | 4 | | | | | 1 | | |
| CC Social and cultural drivers | | 4 | | 8 | | 9 | | | 1 | | | 3 |
| CC Technological barriers | 5 | 1 | | 1 | 1 | | 1 | | | | | |
| CC Technological drivers | 1 | 6 | | 5 | | 2 | | 2 | | 3 | | |

**CC co-occurring with OC**

In Table 17, it can be found how often CC barrier and driver categories co-occur with OC barrier and driver categories. What stands out most, is that the most co-occurring barrier and/or driver categories in the table are the same categories, only they are the closed and open variants:

1. Regulatory and institutional drivers CC and OC (28)
2. Economic and financial barriers CC and OC (26)
3. Market and networking drivers CC and OC (24)
4. Organizational barriers CC and OC (17)
5. Regulatory and institutional barriers CC and OC (16)

The reason that these categories co-occur in this way so often, could be that the closed code used for the quote was not sufficient to cover the entire quote and therefore needed an additional, open code to fully code that part of the interview.

Additionally, it is of value to look into the co-occurring barrier and driver categories that are not the same. Three category combinations stand out, meaning they are co-occurring often:

1. Market and networking barriers CC - Social and cultural barriers OC (12)
2. Market and networking barriers CC - Technological barriers OC (12)
3. Organizational drivers CC - Social and cultural drivers OC (9)

Again, it is noteworthy that although social and cultural drivers were the least mentioned driver category for each actor type, this category is found as the most co-occurring category in combination with organizational drivers (9) as well as market and networking barriers (12).

*Table 17 Co-occurrence table closed code - open code*

| | CC Econ... | CC Econ... | CC Mark... | CC Mark... | CC Orga... | CC Orga... | CC Regu... | CC Regu... | CC Socia... | CC Socia... | CC Tech... | CC Tech... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OC Economic and financial barriers | 26 | 1 | 6 | 1 | 1 | 1 | | 1 | | | 5 | 1 |
| OC Economic and financial drivers | 1 | 8 | | 6 | | 4 | | 1 | | 3 | 1 | |
| OC Market and networking barriers | 3 | | 6 | | 1 | | 1 | 3 | 2 | | | |
| OC Market and networking drivers | 1 | 4 | 3 | 24 | | 7 | | 3 | | 3 | 1 | 2 |
| OC Organizational barriers | | | 1 | | 2 | | 1 | | 1 | | | |
| OC Organizational drivers | | | | 4 | | 17 | | 1 | | 7 | | |
| OC Regulatory and institutional barriers | 1 | 1 | 2 | 1 | 1 | 1 | 16 | 9 | | 1 | 1 | |
| OC Regulatory and institutional drivers | | 3 | 1 | 3 | | 1 | 1 | 28 | | | | 1 |
| OC Social and cultural barriers | 2 | 1 | 12 | 2 | 3 | | | | 9 | 1 | | |
| OC Social and cultural drivers | | 2 | | 2 | | 9 | | 2 | | 11 | | |
| OC Technological barriers | 4 | 1 | 12 | 2 | | | 1 | | 2 | 1 | 7 | 1 |
| OC Technological drivers | | | 1 | 1 | | 1 | | | | | | 8 |

**OC co-occurring with OC**

In Table 18, one can find how often OC barrier and driver categories co-occur with other OC barrier and driver categories. Five category combinations stand out, meaning they are co-occurring often:

1. Technological barriers - Social and cultural barriers (11)
2. Technological barriers - Economic and financial barriers (8)
3. Organizational drivers - Social and cultural drivers (8)
4. Market and networking drivers - Organizational drivers (7)
5. Market and networking drivers - Economic and financial drivers (7)

Again, it is noteworthy that although social and cultural drivers were the least mentioned driver category for each actor type, this category is found as the most co-occurring category in combination with organizational drivers (9), the same as in the co-occurrence analyses of CC-CC and CC-OC.

*Table 18 Co-occurrence table open code - open code*

| | OC Econ... | OC Econ... | OC Mark... | OC Mark... | OC Orga... | OC Orga... | OC Regu... | OC Regu... | OC Socia... | OC Socia... | OC Tech... | OC Tech... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OC Economic and financial barriers | | 3 | 2 | 3 | | 1 | | 1 | 5 | | 8 | 5 |
| OC Economic and financial drivers | 3 | | | 7 | | 1 | | 2 | 2 | | 1 | |
| OC Market and networking barriers | 2 | | | 3 | | | 3 | 1 | 4 | | | |
| OC Market and networking drivers | 3 | 7 | 3 | | | 7 | 1 | 2 | 2 | 2 | 4 | 3 |
| OC Organizational barriers | | | | | | | | | 1 | | 1 | 1 |
| OC Organizational drivers | 1 | 1 | | 7 | | | | | | 8 | | 1 |
| OC Regulatory and institutional barriers | | | 3 | 1 | | | | 5 | | | 1 | |
| OC Regulatory and institutional drivers | 1 | 2 | 1 | 2 | | | 5 | | | 1 | | 1 |
| OC Social and cultural barriers | 5 | 2 | 4 | 2 | 1 | | | | | 1 | 11 | 1 |
| OC Social and cultural drivers | | | | 2 | | 8 | | 1 | 1 | | | 1 |
| OC Technological barriers | 8 | 1 | | 4 | 1 | | 1 | | 11 | | | 2 |
| OC Technological drivers | 5 | | | 3 | 1 | 1 | | 1 | 1 | 1 | 2 | |

## 4.4 Synthesis

Per category, a summary of factors will be presented that should be taken into account when trying to mitigate the barriers towards sustainability in the housing construction industry. This part draws on

the most important barriers and drivers for all actor types as well as the different project types (property was internally or externally developed) and co-occurring categories that were found in the previously presented results. On the one hand, most important means that certain barriers and drivers were mentioned very often, which indicates that the interviewed actors often encounter these in their daily work. On the other hand, most important also includes barriers and drivers that are not included in the top 10 lists of barriers and drivers, but are important to include in the analysis, since they (potentially) address underlying causes and problems.

Recapitulating the six categories that will be discussed in corresponding order throughout this chapter, are the following:

1. Economic and financial
2. Market and networking
3. Organizational
4. Regulatory and institutional
5. Social and cultural
6. Technological

### 4.4.1 Category 1: Economic and financial

Economic and financial factors can prove to be important barriers when it comes to making the construction chain more sustainable. The products produced by a subcontractor are seen as more expensive by the main contractor and developing parties, which is often true. Sustainability and sustainable innovation generally cost a lot of time and money. Since actors are not used to working with certain sustainable products, they conduct a risk assessment, which also causes the price to increase. Additionally, sustainable construction equipment will not be used in the near future, because the current non-sustainable construction equipment has not yet (fully) depreciated. The small margins in the construction industry, the high failure costs and the uncertainty of the housing market leave little space for implementing sustainable products while at the same time realizing a financially viable project.

A driving factor in the process of making the construction chain more sustainable often involves financial gain. Financial gains can be obtained in numerous ways and oftentimes will cause market forces to be incentivized. When companies and customers see the value of sustainability, it will gain popularity and make people want to pay extra money for it. Sharing financial burdens in the housing construction chain will be a challenge, but can prove to be a major accelerating factor towards sustainability. This will probably take a long time to implement, which is not the case for another driver in this category: penalizing polluting actors in the housing construction chain.

The economic and financial category has proven to be the number one category when it comes to how often barriers in this category have been mentioned during the interviews. Regardless of actor type or the project being developed internally or externally, it was found that economic and financial factors hinder the housing construction industry from becoming more sustainable.

Conversely, this is not true when analyzing which factors drive sustainability forwards. For none of the actors, the economic and financial category was in the top three most important driver categories (most important based on how often drivers in this category were mentioned during the interviews). This is not to state that this category does not hold any value in driving the implementation of sustainability forward. It mainly indicates that they perceive other driver categories to hold more possible drivers towards sustainability compared to economic and financial drivers. From the interviews, it does not become clear why the economic and financial barrier category was the most important to all actor types as opposed to the economic and financial driver category.

Looking at co-occurring categories, three correlations stand out, meaning these categories relate to each other (were mentioned in co-occurrence in the interviews):

1. Economic and financial drivers - Technological drivers
2. Economic and financial barriers - Technological barriers
3. Economic and financial drivers - Market and networking drivers

These co-occurring category findings indicate that economic and financial barriers, as well as drivers, are related to the technological category. This may indicate that the amount of available financial resources can limit or stimulate any research into and implementation of innovative techniques. Furthermore, when actors have compatible ways of operating, they can decide to share financial burdens together. This increases the chance of seizing sustainable opportunities, such as acquiring and implementing innovative technology in the actors' operations. These findings, however, should be analyzed further to gain a better understanding of how they relate, as well as how they can be utilized in a combined way to strengthen the push towards sustainability.

### 4.4.2 Category 2: Market and networking

The collaboration between the subcontractor(s), main contractor and developing party influences the process of making the construction chain more sustainable to a great extent. This process can be negatively influenced by several aspects. If the actors in the chain do not properly understand how SSCM should be properly implemented, this can manifest in insufficient responsibility, poor communication and therefore poor collaboration. The non-implementation or little implementation of sustainable products can be a result of several factors. It can be because a party does not want to work with a product, but it may also be due to parties not being prepared to jointly invest in sustainability. An aesthetic preference by the architect can result in design choices that are not sustainable. Some of these barriers may be caused by the fact that the chain actors arranged meetings too late, causing useful expertise for sustainable construction to no longer be implemented (in time).

Communication is one of the most important aspects that contributes to the process of making the housing construction chain more sustainable. Communicating as often and openly as possible in the earliest stages of the housing construction project will increase chances of having every actor on the same page and them being aware of the sustainability requirements of projects. During the collaboration, the main contractor acquires sustainability knowledge from other actors in the supply chain and passes it on to the subcontractor and the developer, thereby making everyone aware of the latest developments and creating possibilities to support each other. Another driver in this category is the use of a sustainable architect and a contractor with sustainable purchasing knowledge, as well as to exclude parties that do not wish to operate sustainably.

The market and networking category was found to be an outstanding category as both a barrier category and a driver category. For subcontractors and property developers, it can be concluded to be one of the most important categories for both barriers and drivers. This indicates that it is an important category to be studied further when it comes to how to engage subcontractors and property developers more and better in the sustainability movement. It is noteworthy to state explicitly that it seems to be the case that market and networking barriers and drivers are not the main concern for the main contractor. From the interviews, it does not become clear what the cause may be for this observation. It is possible that the main contractor is not fully aware of how barriers pertaining to the market and networking category may influence implementation of sustainability in the housing construction supply chain. Nonetheless, it cannot be said that this category is not important to take into account for this actor.

Looking at co-occurring categories, four correlations stand out:

1. Market and networking drivers - Social and cultural drivers
2. Market and networking drivers - Organizational drivers
3. Market and networking barriers - Social and cultural barriers
4. Market and networking barriers - Technological barriers

These co-occurring category findings indicate that market and networking barriers, as well as drivers, are related to the social and cultural category. This could indicate that social and/or cultural beliefs from the actors within the supply chain (network) are essential for the implementation of sustainability in the housing construction sector. Moreover, the co-occurrence of the market and networking category with the organizational category could signal that organizational drivers may have a positive impact on the housing construction supply chain (network) as well as the other way around. Organizational measures may influence the way the actor operates in the supply chain, thereby prompting other actors to undertake sustainable actions as well, which in turn positively influences (the sustainable collaboration in) the supply chain as a whole. These findings, however, should be analyzed further to gain a better understanding of how they relate, as well as how they can be utilized in a combined way to strengthen the push towards sustainability.

#### 4.4.3 Category 3: Organizational

An organization can influence the process of making the housing construction chain more sustainable in positive and negative ways. One important obstacle to sustainability is when an organization's top management shows too little commitment (or none at all) to sustainability. Employees are, in a way, an extension of top management and brings the organization's mission, vision and strategy into practice. This way, if top management has no or little commitment to sustainability, there will be insufficient means and focus on sustainability to make a change in this regard. Subsequently, the entire housing construction chain experiences a lack of focus on and commitment to sustainability. In addition, a hindering factor is when it is not clear for employees where to acquire the right information for them to work with, produce or buy sustainable products. This can result in less sustainable operations and implementation.

Conversely, a driving factor for sustainability would be actual commitment to and support from top management towards sustainable improvements. Additionally, educating staff on gaining knowledge and using sustainable methods will push sustainability, as well as actively listening to (often young) employees with innovative thoughts. This will generate inspiration among employees and lead to new solutions towards sustainability.

The organizational category was the least mentioned barrier category for all actor types. This does not necessarily mean that there are no barriers to be mitigated that are organizational in nature, but for the actors in this case study, it is the category that provides the least barriers or risks in the pursuit for sustainability. Noteworthy is that organizational drivers were mentioned the most by main contractors.

Looking at co-occurring categories, two correlations stand out:

1. Organizational drivers - Social and cultural drivers
2. Organizational drivers - Market and networking drivers

As discussed in paragraph 4.4.2, the co-occurrence of the market and networking category with the organizational category could signal that organizational drivers may have a positive impact on the housing construction supply chain (network) as well as the other way around. Additionally, there seems to be some relation between organizational drivers and social and cultural drivers. These

findings, however, should be analyzed further to gain a better understanding of how they relate, as well as how they can be utilized in a combined way to strengthen the push towards sustainability.

#### 4.4.4 Category 4: Regulatory and institutional

The government's laws and regulations can have a negative and even delaying role in the process of making the housing construction chain more sustainable. In this case, it is about making regulations and providing support. Barriers can be that there are not enough rules or rules are ambiguous and thus cannot be clearly interpreted by actors in the housing construction chain. Moreover, changing or tightening regulations too quickly over time causes the construction chain actors to be unable to keep up with the pace of changing legislation.

Furthermore, it seems that there is a negative way of communicating from the government when it comes to enforcing legislation. The government's communication style can be described as fear based and imposing the rules, whereas governmental campaigns could also be based on positive communication and motivating organizations to contribute to the push for sustainability. Additionally, the government should offer a support(ive) system with regulations and effective legislation. It is important for sustainable operations to be integrated into proactive plans and that a long-term vision is propagated in a positive manner. This can be done by giving bonus points and incentives for sustainable operation.

The regulatory and institutional category is mainly important for the main contractor as barrier and driver category, as well as for subcontractors, although only regarding driving factors. Subsequently, there is a difference for this category when it comes to the housing projects being developed internally versus externally. For externally developed projects, regulatory and institutional drivers are the second most important category, whereas for internally developed projects, this category was mentioned less frequently. Looking at co-occurring categories, there are no correlations that stand out.

#### 4.4.5 Category 5: Social and cultural

An organization's culture influences the sustainability in the housing construction industry, since this culture affects the focus and choices that are made. An obstruction towards sustainability in this category would be that people within an organization have no desire to use new sustainable methods. They like to stick to what they know and traditionally work with. A factor therein may be that they lack knowledge about sustainability and therefore cannot oversee the consequences of their actions. This may be an underlying reason for ignorance and preference towards traditional ways of working. Moreover, it should not be forgotten that people are hardwired to resist any (major) change (Strebel, 1996). Attention should be paid to transforming this attitude in order to generate opportunities for sustainability.

Drivers from the social and cultural category can also be employed to facilitate the push towards sustainability in the housing construction chain. One such driver is to actively engage employees in making the housing construction processes more sustainable. Encouraging a feeling of responsibility and participation will increase chances of employees wanting to contribute to this process. Additionally, public pressure is a powerful tool in getting organizations to instigate change.

Although it has not been mentioned often for any of the three actor types, the social and cultural category is an important category in co-occurrence with other categories. This may indicate that this category addresses underlying problems (barriers) or opportunities (drivers). It is beyond the scope of this thesis to focus on this correlation, but it is important to see how and why social and cultural factors may relate to the pursuit of sustainability in the housing construction industry. Therefore, further research needs to be conducted into this area.

Looking at co-occurring categories, four correlations stand out:

1. Social and cultural barriers - Market and networking barriers
2. Social and cultural barriers - Technological barriers
3. Social and cultural drivers - Organizational drivers
4. Social and cultural drivers - Market and networking drivers

These co-occurring category findings indicate that social and cultural barriers, as well as drivers, are related to the market and networking category. As discussed in paragraph 4.4.2, this could indicate that social and/or cultural beliefs from the actors within the supply chain (network) are essential for the implementation of sustainability in the housing construction sector. Moreover, there seems to be some relation between social and cultural drivers and organizational drivers, as well as between social and cultural barriers and technological barriers. These findings, however, should be analyzed further to gain a better understanding of how they relate, as well as how they can be utilized in a combined way to strengthen the push towards sustainability.

#### 4.4.6 Category 6: Technological

Technological potential and innovations can have a major impact in how the sustainable landscape in terms of options and operations evolves. It also has the potential of slowing down or frustrating sustainability in the housing construction industry. One evident barrier is when there is no or insufficient machinery to operate (more) sustainable. Additionally, a lack of adequate electrical infrastructure on construction sites is a blocking factor - organizations may want to operate in more sustainable ways and may be willing to invest in sustainable machinery, but when the electrical infrastructure on construction sites is inadequate, their efforts may be ineffective. Moreover, having insufficient knowledge about the possibilities or implementation of technical solutions prevents organizations from realizing the full potential of sustainability in the housing construction industry.

On the other hand, having adequate technological information available on sustainability is a driving factor. This information can be obtained from qualitative and quantitative (measurement) data obtained in scientific research and frequent collaboration with technical universities. From the interviews, it emerged that technological information was not available to the extent needed to increase sustainable innovation. Therefore, it would help to install a central communication point aimed at providing correct and up-to-date information available within the organization regarding technological knowledge and experience. Lastly, a housing construction process that allows some additional drying time so that housing projects need less cement in their concrete applications will help to reduce emissions. To compensate for lost time, the housing construction industry can explore options to increase the use of prefabricated elements in the construction of houses.

For subcontractors, the technological category was identified as a driving factor from subcontractors perspectives in particular and also seems to be more important for internally developed housing projects compared to externally developed housing projects. Apart from these observations, the technological category does not stand out as one of the most important barrier categories as an individual category. However, the technological category does come up as an important barrier category in co-occurrence with other barrier categories.

Looking at co-occurring categories, four correlations stand out:

1. Technological barriers - Market and networking barriers
2. Technological barriers - Social and cultural barriers
3. Technological barriers - Economic and financial barriers
4. Technological drivers - Economic and financial drivers

These co-occurring category findings indicate that technological barriers, as well as drivers, are related to the economic and financial category. As discussed in paragraph 4.4.1, this may indicate that the amount of available financial resources can limit or stimulate any research into and implementation of innovative techniques. Furthermore, when actors have compatible ways of operating, they can decide to share financial burdens together. This increases the chance of seizing sustainable opportunities, such as acquiring and implementing innovative technology in the actors' operations. Moreover, there seems to be some relation between technological barriers and market and networking barriers on the one hand, and between technological barriers and social and cultural barriers on the other hand. These findings, however, should be analyzed further to gain a better understanding of how they relate, as well as how they can be utilized in a combined way to strengthen the push towards sustainability.

# Chapter 5: Discussion

This chapter discusses two things: first, the findings from the research are compared to the current knowledge in the academic field, thereby elaborating on the contribution of this research to the literature. Second, limitations of this research are assessed.

## 5.1 Comparing findings to literature

During the literature study, barriers and drivers from other industries were found that influence the implementation of sustainability in their respective production chains. Based on these literature findings, the closed codes were established that were used to code the transcribed interviews. Many of these closed codes were found throughout the interviews for the identification of barriers and drivers in the housing construction industry. This means that these barriers and drivers apply to multiple industries including that of the housing construction. This, in turn, may indicate that the origins of these barriers and drivers towards the implementation of sustainability should be looked for not only within the housing construction industry, but the possibility should be considered that the root cause(s) for these barriers and drivers may be found at a higher level. Studying these barriers and drivers outside of the housing construction industry is therefore important in order to accelerate sustainability efforts in multiple industries. Some of the barriers and drivers that were found during the literature study and subsequently confirmed in the interviews, were the following:

**Barriers**

1. Lack of money to invest (investment is too high). This barrier was also observed in the steel industry (Orji, 2019; Prasad et al., 2018), clothing industry (Tumpa et al., 2019), chemical industry (Shohan et al., 2019) and car industry, (Drohomeretski, Da Costa, & De Lima, 2014; Luthra, Kumar, Kumar, & Haleem, 2011).
2. Lack of adequate government support system. This can manifest in several ways, e.g. legislation being multi-interpretable, implementation of laws being too soon and a lack of guidance. This barrier was also observed in the car industry (Drohomeretski et al., 2014; Luthra et al., 2011) and clothing industry (Tumpa et al., 2019).
3. Insufficient knowledge about sustainability. This can be technological knowledge, but also applies to sustainability in general and how to implement this into the supply chain. This barrier was also observed in the steel industry (Orji, 2019; Prasad et al., 2018) and manufacturing industry (Gupta, Kusi-Sarpong, & Rezaei, 2020; Kiefer, Del Rio Gonzalez, & Carrillo-Hermosilla, 2019).

**Drivers**

1. Strong collaboration agreements among chain actors. This driver was also observed in the manufacturing industry (Gupta et al., 2020; Kiefer et al., 2019).
2. A support system by the government with regulations and effective legislation. This driver was also observed in the car industry (Drohomeretski et al., 2014; Luthra et al., 2011).
3. Top management commitment to sustainability. This driver was also observed in the car industry (Drohomeretski et al., 2014; Luthra et al., 2011) and steel industry (Orji, 2019; Prasad et al., 2018).

Apart from the barriers and drivers that were found during the literature review and provided the basis for the closed codes, a number of new barriers and drivers were found during the interviews and labeled as open codes. The reason that new barriers and drivers were found is be twofold: on the one hand, the newly identified barriers and drivers were (closely) related to the barriers and drivers from the literature study, but the closed codes did not fully capture the meaning of the identified barrier or

driver. On the other hand, some barriers and drivers were newly discovered through this study and apply specifically to the (housing) construction industry. The barriers and drivers mentioned below are examples of newly found barriers and drivers.

**Barriers**

1. The failing costs of projects are too high and there is not enough financial capacity to absorb these costs, preventing organizations from taking risks and implementing sustainability.
2. Former members of cement companies take part in norm setting committees regarding the required amount of cement in one $m^3$ concrete.
3. There is no adequate electric infrastructure to supply an increased amount of electric machinery on construction sites, thus limiting the number of sustainable options regarding machinery usage during the construction phase.

**Drivers**

1. Hire a sustainable architect for housing construction projects, whose mandate is to look for chances to implement more sustainable options.
2. Allow more drying time during the construction of houses, since this allows (sub)contractors to use less cement per $m^3$ concrete.
3. Recognizing that the property developer is a starting point in which choices are made that will influence the emissions later in the project. Realizing this helps to define the appropriate interventions in the housing construction process.

### 5.1.1 Contribution to the academic field

The way this thesis contributes to the academic field is threefold. First, it confirms earlier found barriers and drivers from other industries that also apply to the housing construction industry, as discussed in the previous paragraphs. Second, this thesis adds to existing academic literature by identifying barriers and drivers that are unique to the housing construction industry. Understanding these barriers and drivers is important not only for nuancing the academic literature, but also holds value for actors' understanding of what blocks and accelerates the implementation of sustainability in the housing construction industry (including the government). Lastly, this research included a comparison of two types of housing projects: one project where the property was developed internally by the main contractor and one where the property was developed externally. This analysis was not conducted prior to this research.

## 5.2 Research limitations

In defining the scope of this thesis, choices were made that impact the research design and its outcomes. Therefore, it is inevitable to find that there are limitations that have a potential impact on this thesis. First, the results were obtained through a case study of one main contracting party, i.e. the BAM, and their chain partners in the housing construction industry. This implies that not all barriers and drivers that were found, may apply to other similar actors within this industry. In this case study, two supply chains for two project types were studied (internally and externally developed projects). Therefore, the results are not quantifiable based on this research alone.

Second, the interviewed actors were limited to three actor types in the housing construction supply chain: subcontractors, main developers and property developers. The chain, however, is composed of numerous other actors that did not fall in the scope of this thesis. For this thesis, the choice was made for these three actor types, since they are perceived to hold the most influence over the amount of $CO_2$ and $NO_x$ emissions in the housing construction industry. Moreover, for subcontractors, the same is true: there are more subcontractors that are in business with BAM or other main contracting actors. For this initial exploration of barriers and drivers in the housing construction industry, the most

polluting subcontractors were interviewed to gain insights into the barriers and drivers they encounter in their collaboration with main contractor BAM.

Third, this case study focuses on the housing construction supply chain within the Netherlands. This limits the quantifiability of the results presented in this research, since other countries or other continents may experience different barriers and/or drivers and may use different ways of dealing with these barriers and drivers.

Fourth, this thesis briefly touched upon governmental and policy instruments that hinder or facilitate the implementation of sustainability in the housing construction industry. Governmental actors, however, were not included in the respondent selection. This means that potential insights into the processes on the side of the government are not (fully) included in the results and recommendations in this research.

Lastly, interviewing more organizations and people within the housing construction supply chain may provide more insights into the barriers and drivers that influence the implementation of sustainability in the supply chain. Nonetheless, data saturation was reached in the results, implying that the respondents provided congruent information in the twelve interviews that were conducted.

# Chapter 6: Practical recommendations

This chapter elaborates on the practical recommendations based on the findings of this research. This advice will be discussed per actor type and include recommendations from the different categories that were distinguished in this research. The list presented in this chapter are composed based on a combination of the most actionable recommendation, the most important findings regarding the barriers and drivers and considerations about addressing possible underlying root causes of the barriers found in the research. For each actor, ten recommendations are presented in this chapter. A complete list of practical recommendations classified by category can be found in Appendix C.

**Main contractors**

- Aim at sharing financial burdens as much as possible with the subcontractors and other chain partners when investing in new sustainable operations. Some investments in sustainable operations are too high for a single actor to realize. Therefore, it is recommended that supply chain actors find effective ways to share financial burdens in housing projects. This will leave more financial room to implement more sustainable measures in the project. It should be included to make arrangements for sharing the financial profits that may arise from this burden sharing.
- Ensure sincere commitment from the organization's top management on sustainability. This includes ensuring that top management values collaboration with trustworthy, sustainability-oriented parties over other possible partners.
- Propagate this sustainable corporate culture, thereby inspiring employees and create support within the organization to become more sustainable.
- Create awareness, trust and environmental collaboration agreements between the chain actors in the housing construction industry, thereby enforcing the focus on sustainability between actors.
- Strengthen the construction process by limiting failing costs to ensure more financial space for the implementation of sustainable operations. Failing costs can be decreased by ensuring projects are evaluated and lessons learned are shared within the organization as well as among the supply chain partners.
- Share information on sustainability between the property developers, the procurement division and the knowledge division of the main contractor.
- Install a central communication point for employees to find the correct and most updated information available within the organization regarding technical knowledge and experience.
- Establish performance goals with supply chain partners to track sustainability improvements.
- Gain access to advanced technology (information) to increase chances to implement sustainable operations. This can be done by consulting technological universities and other research facilities.
- Invest time and money into creating more sustainable production methods, such as extending the drying period of concrete to decrease the use of cement.

**Subcontractors**

- Aim at sharing financial burdens as much as possible with the main contractor and other chain partners when investing in new sustainable operations. Some investments in sustainable operations are too high for a single actor to realize. Therefore, it is recommended that supply chain actors find effective ways to share financial burdens in housing projects. This will leave more financial room to implement more sustainable measures in the project. It should be

included to make arrangements for sharing the financial profits that may arise from this burden sharing.

- Ensure sincere commitment from the organization's top management on sustainability. This includes ensuring that top management values collaboration with trustworthy, sustainability-oriented parties over other possible partners.
- Propagate a sustainable corporate culture, thus inspiring employees and create support within the organization to become more sustainable.
- Implement measures to ensure good and timely communication about sustainability requirements and products from the earliest possible stages in the collaboration. This may differ per project, but increased focus on timely (early) communication enables informed decision making in favor of sustainable solutions.
- Strengthen the construction process by limiting failing costs to ensure more financial space for the implementation of sustainable operations. Failing costs can be decreased by ensuring projects are evaluated and lessons learned are shared within the organization as well as among the supply chain partners.
- Create awareness, trust and environmental collaboration agreements between the chain actors in the housing construction industry.
- Stipulate the advantage of sustainability and sustainable products that you wish to sell or implement.
- Establish performance goals with the other chain actors to measure sustainability improvements.
- Increase the presence of sustainability knowledge in the company.
- Adopt an open attitude towards new ideas from external parties as well as from (internal) employees.

**Property developers**

- Ensure sincere commitment from the organization's top management on sustainability. This includes ensuring that top management values collaboration with trustworthy, sustainability-oriented parties over other possible partners.
- Propagate this sustainable corporate culture, thus inspiring employees and create support within the organization to become more sustainable.
- Create and/or strengthen the organization's sustainability strategy towards other actors in the housing construction chain, (there)by engaging and motivating them to increase their focus on sustainability.
- Implement measures to ensure good and timely communication about sustainability requirements and products from the earliest possible stages in the collaboration. This may differ per project, but increased focus on timely (early) communication enables informed decision making in favor of sustainable solutions.
- Employ a sustainability architect for housing construction projects.
- When developing a housing project, try to see where small sustainable options can be used instead of traditional ways: small steps count.
- Standardize the choice for more sustainable options within the design and development of housing projects.
- Create awareness, trust and environmental collaboration agreements between the chain actors in the housing construction industry.
- Implement work processes and policy on how to preserve knowledge about sustainable operations and alternatives so other projects can build upon.
- Gain access to advanced technology (information) to increase chances to implement sustainable operations. This can be done by consulting technological universities and other research facilities.

**Governmental actors**

Recommendations towards the government are presented here as well, since they are responsible for steering both the (housing) construction industry and society as a whole towards a more sustainable future. Since the housing construction actors are heavily dependent on the legislation set by the government, the approach towards more sustainable operations should be an integrated approach that includes the government.

- Ensure legislation does not contradict with other parts of legislation and is unambiguously formulated. To ensure unambiguous language, the text for the proposed policy can be tested by having it proofread by a focus group.
- Draft a long term vision and translate this into policy that is predictable in the steps that organizations in the housing construction chain are required to take. These steps should therefore provide a clear and realistic timeline for organizations so they know what they should adhere to without question.
- Run campaigns towards organizations using positive language that encourages people to feel like they can actively contribute to working towards a solution to a problem. Legislation is coercive in nature, but that does not mean communication should be negative and restrictive as well.
- Use positive reinforcement measures such as bonus points and (tax) incentives for organizations when they are working towards more sustainable operations. On the other hand, use negative reinforcement measures such as increased taxes or other penalties when they emit too much emissions.
- Develop and provide (templates of) collaboration agreements.

# Chapter 7: Conclusion

## 7.1 Introduction and context

In this chapter, the conclusions of this research will be presented. This research is an exploratory analysis on what elements influence the implementation of sustainability in the housing construction supply chain during the construction of houses in the Netherlands. By emphasizing on the collaboration between actors in the housing construction chain, this research aimed to analyze potential barriers and drivers in the pursuit of sustainability. To obtain these results, a case study was carried out, which was based on literature study and semi-structured interviews. From the housing construction supply chain, twelve interviews were conducted with representatives from six subcontractor companies, the BAM as main contracting party, and two development companies. This research' aim was to gain insights into the current and future collaboration within the supply chain of the housing construction industry between three actor types, i.e. subcontractors, main contractors and property developers. For six categories, barriers and drivers were investigated: economic and financial, market and networking, organizational, regulatory and institutional, social and cultural, and technological. Eventually, actions were drafted based on the identified barriers and drivers in order to answer the main research question: *How can the collaboration between actors in the Dutch housing construction industry be improved in the pursuit of sustainable supply chain management?*

## 7.2 Research questions answered

*SQ1 Which actors in the housing construction supply chain hold the most influence in producing the majority of $CO_2$ and $NO_x$ emissions?*

The housing construction supply chain consists of a wide variety of actors with key players in this chain being main contractors, property developers and so-called first tier subcontractors. Main contractors interact with both the property developer and the first tier subcontractors and therefore play an important central role in the chain. Additionally, property developers are highly influential in the design of the construction project. This means they make design choices specifying the materials that need to be used in the project that main contractors and (first tier) subcontractors carry out. Furthermore, subcontractors are responsible for delivering the commodity or service specified in the contract between them and the main contractors. The greenhouse gas $NO_x$ emissions that occur during the production of these goods or the delivery of services need to be taken into account when analyzing the barriers and drivers to implement sustainability in the supply chain. In this thesis, the focus for subcontractors is on so-called first tier subcontractors, which refers to subcontractors that are directly contracted by the main contracting party. These subcontractors often rely upon (second tier) subcontractors, e.g. cement suppliers. From the Life Cycle Assessment in Chapter 2, it was found that the top four most emitting first tier subcontractor types were companies that provided steel, concrete, brick and construction site preparation.

*SQ2 What are the known barriers and drivers during the implementation process of sustainability for traditional supply chain management in relevant major industries?*

From the literature study, barriers and drivers emerged for the implementation process of sustainable supply chain management for different studies, respectively the car industry, chemical industry, manufacturing industry, clothing industry, steel industry and construction industry. These barriers and drivers were subsequently divided into six categories that can be found in Table 19.

*Table 19 Barrier and driver categories*

| Category | Description |
|---|---|
| Economic & financial | Refers to monetary barriers and drivers, including investments, return on investment and (uncertainty of) profit |
| Market & networking | Includes market dynamics and actors, among others competitors, market (un)certainty, suppliers, (sub)contractors, other supply chain actors |
| Organizational | Considers "internal" factors, includes (top) management commitment and employee involvement |
| Regulatory & institutional | Includes legislative measures, effectiveness of legal/governmental support system, incentives, institutional (government) standards |
| Social & cultural | Refers to social awareness, customer and employee behavior and (business) routines |
| Technological | Includes the (un)availability of (in)appropriate technology, its design and technical knowledge and training |

The barriers and drivers most relevant to this research are listed below. The full list of barriers and drivers found in other industries can be found in Appendix A.

**Barriers**

- Lack of money to invest (economic and financial barrier)
- Bad collaboration between companies (market and networking barrier)
- Stay with traditional technology and culture (social and cultural barrier)
- Insufficient environmental competencies (regulatory and institutional barrier)
- Lack of understanding and knowledge on SSCM among organizations in the chain (market and networking barrier)

**Drivers**

- Create a market pull (economic and financial driver)
- Create an environmental collaboration between main contractor, subcontractor and property developer (market and networking driver)
- A support system offered by the government with regulations and effective legislation (regulatory and institutional driver)
- Create awareness among involved parties (market and networking driver)
- Create a sustainable corporate culture (organizational driver)

*SQ3 What are the barriers and drivers that the most influential actors in the housing construction industry encounter in their collaboration to implement sustainability in the housing construction industry's supply chain?*

From the interviews, an extensive amount of barriers and drivers were identified that actors encounter in the implementation of sustainability in the housing construction industry. A full overview of all barriers and drivers specified per actor type and project type can be found in Chapter 4. The most relevant industry specific barriers and drivers are listed below.

**Barriers**

- Institutional rules are not clear enough and multi-interpretable (regulatory and institutional barrier)
- The price for a sustainable product is too high to implement it (economic and financial barrier)
- Uncertainties in the market competition (economic and financial barrier)

- Not clear for all company employees where to acquire the right information for them to work, produce of buy sustainable products (organizational barrier)
- Subcontractor gets involved in the project too late, so that useful expertise can no longer be used (market and networking barrier)

**Drivers**

- Get rid of partners that do not want to work sustainable (market and networking driver)
- Main contractor communicates with subcontractors and property developers and shares their information (market and networking driver)
- Educate staff to use sustainable methods (organizational driver)
- Share financial burdens together (economic and financial driver)
- Long term vision of the government (regulatory and institutional driver)

**Comparison of barrier categories between actor types**

For all actors, the economic and financial category was found to be the most important, meaning that the barriers within this category where mentioned the most compared to other categories. Furthermore, it is remarkable that subcontractors and property developers experience many barriers in the market and networking category, whereas main contractors experience this to a lesser extent. Conversely, main contractors experience more barriers in the regulatory and institutional category. This indicates that the focus of main contractors lies elsewhere when identifying barriers than subcontractors and property developers. It could therefore be argued that these actor types perceive the dynamics in the supply chain differently.

**Comparison of driver categories between actor types**

Building on the conclusion that subcontractors and property developers experience a lot of barriers in the market and networking category, it is also true that these two actor types perceive this category to hold a lot of drivers in the pursuit of sustainability in the supply chain. Again, for main contractors it was found that the market and networking category was not mentioned as much compared to the other two actor types. Instead, they identify the organizational category to be an important driver category.

For both barriers and drivers, it shows that subcontractors and property developers focus on the market and networking category, indicating they look more at the supply chain compared to main contractors. For main contractors, it seems they focus more on regulations, institutional barriers and drivers from within their own organization.

**Comparison between barriers and drivers for internally and externally developed projects**

For most barrier and driver categories, it emerged that the mentioned barriers and drivers were mentioned in approximately the same quantity for both internally and externally developed projects. There were no outstanding differences found in the amount of identified barriers and drivers for both project types. This finding implies that there is no real difference in the barrier and driver categories experienced in the supply chain based on whether a project is developed internally or externally.

**Category co-occurrence**

Furthermore, a co-occurrence analysis was conducted that focused on how often different barrier and driver categories were mentioned together in the interviews. When certain categories are mentioned jointly by the actors, this could indicate that these categories reinforce each other either negatively (barriers) or positively (drivers). For the co-occurring barrier categories, a number of observations were made. First, the technological barrier category is regularly mentioned in co-occurrence with a number

of other barrier categories: (1) market and networking, (2) social and cultural and (3) economic and financial. This may suggest that innovative techniques may not be researched further or implemented because they are either too expensive or there may be negative cultural beliefs or attitudes towards how important innovative techniques may be. Furthermore, the social and cultural barrier category is mentioned often jointly with the market and networking barrier category. This could indicate that social and/or cultural beliefs from the actors within the supply chain (network) are hindering the implementation of sustainability in the housing construction sector.

Additionally, observations were made for co-occurring driver categories. The market and networking driver category was mentioned regularly in co-occurrence with multiple other driver categories: (1) organizational, (2) social and cultural and (3) economic and financial. The co-occurrence of the market and networking category with the organizational category could signal that organizational drivers may have a positive impact on the housing construction supply chain (network) as well as the other way around. Organizational measures may influence the way the actor operates in the supply chain, thereby prompting other actors to undertake sustainable actions as well, which in turn positively influences (the sustainable collaboration in) the supply chain as a whole. Furthermore, when actors have compatible ways of operating, they can decide to share financial burdens together. This increases the chance of seizing sustainable opportunities, such as acquiring and implementing innovative technology in the actors' operations.

*SQ4 What improvements for sustainable supply chain management in the housing construction industry can be found based on the identified barriers and drivers?*

Based on the identified barriers and drivers, a number of improvements are recommended. In this conclusion, a summary of the most important improvements is given. The full list of recommendations can be found in Chapter 6 and Appendix C.

- Share knowledge with all actors in the supply chain. Ensure that knowledge sharing is done at the right moment in the construction process so that the relevant actor(s) therefore can operate more sustainably. This will provide opportunities for a sooner and less costly implementation of sustainability, because the later changes are made in the process, the more costly this is.
- Develop a sustainable corporate culture that is reinforced both top-down and bottom-up in the organization. As people are hardwired to resist change in general, focusing on sustainability within corporate culture and taking measures to cope with people's resistance will help to transform employees' attitudes to generate more opportunities for sustainability. Furthermore, it is important to not only focus on the actor's own organization, but also to focus on other actors in the supply chain. Organizational changes towards sustainability can positively affect the rest of the supply chain, since a focus on sustainability from one organization can lead to selecting mainly sustainability-oriented supply chain partners. Having more than one actor focus on sustainability in the supply chain will increase chances of successfully implementing sustainability in the supply chain.
- Some investments in sustainable operations are too high for a single actor to realize. Therefore, it is recommended that supply chain actors find effective ways to share financial burdens with each other in housing projects. This will leave more financial room to implement sustainable measures in the housing construction project, thereby decreasing the amount of emitted greenhouse gases and $NO_x$ emissions.
- Institutions draft long term visions for the environment and subsequently translate this into policy. Too often, this policy is not clear, multi-interpretable or even sets very tight implementation

deadlines. To this end, it is important to implement policy that is predictable in its implementation and unambiguously formulated. Positive reinforcement measures such as a bonus point system and (tax) incentives for organizations can be employed to provide organizations with more motivation or financial resources to focus on sustainability. Conversely, negative reinforcement measures such as increased taxes or other (financial) penalties can be used for organizations that do not meet the set standards in policy.

Based on the answers to the four subquestions, the main research question can be answered:

*How can the collaboration between actors in the Dutch housing construction industry be improved in the pursuit of sustainable supply chain management?*

To increase the implementation of sustainability in the housing construction supply chain, underlying problems in the collaboration between the actors in the housing construction industry need to be addressed. This calls for an integrated approach, where not only executive organizations work through vicious cycles and persistent problems, but also governmental and other legislative actors fulfil an important facilitating role. In this thesis, representatives from the actors in the housing construction industry that are very influential in polluting during housing projects were interviewed. Main contractors oversee the whole project, therefore being an critical actor in overseeing the entirety of pollution in these housing projects. Property developers have a very important role regarding design choices that are made in the earliest stages of housing projects. Additionally, main contractors such as BAM work with a wide variety of subcontractors that are important actors in the amount of emitted greenhouse gases and $NO_x$ emissions produced during housing construction projects. The formulated actions in Chapter 6 aim to provide these actors are based on the barriers and drivers that were found during the interviews and aim to provide insights into ways they can improve their ways of working and their collaboration. To improve their ways of working (together), respondents indicated during the interviews that it would be accommodating to find ways to jointly invest in sustainable operations, products and machinery. Sharing financial burdens makes it easier to acquire more sustainable options and will leave more financial capacity. Besides sharing the financial burden, it was also mentioned that relevant knowledge about sustainability should be shared more and earlier in projects. This way, every actor in the project can benefit from and apply this knowledge. The interviews also indicated that there is a critical role for top management in the pursuit of a more sustainable housing construction supply chain. Genuine commitment and support from top management will have a positive effect on sustainable choices that will be made during projects, since there will be an increased focus on advancing sustainability. This is closely related to another recommendable focus area that emerged in the interviews: implementing a corporate culture that is concerned with sustainability. People are hardwired to resist change in general, which is also true for sustainability. By focusing on sustainability within corporate culture and taking measures to actively address this resistance, people's attitudes can be transformed to generate opportunities for sustainability. Lastly, governmental and legislative actors play an important facilitating role in enabling housing construction actors to operate in more sustainable ways. Chapter 6 holds actionable recommendations specifically for governmental actors that address penalizing and incentivizing companies in the housing construction industry to operate more sustainably. Moreover, recommendations are made regarding the timeline in which the implementation of legislation regarding sustainability takes place. Currently, legislation is sometimes implemented too fast. Companies do not get enough time to implement step one of a sustainability legislative plan before they have to move to step two. Additionally, another legislative barrier that came up in the interviews was that laws and regulations were ambiguous, lacking or otherwise not clear. Concluding, to improve the collaboration between different actors, intrinsic motivation should be cultivated among the chain actors, which should be supported and supplemented by governmental

policy instruments in order to work effectively towards a more sustainable housing construction supply chain.

## 7.3 Recommendations for further research

Besides practical recommendations for the supply chain actors in the housing construction industry, several recommendations can be made for further research. First of all, two supply chains (internally versus externally developed) were subjected to this analysis, but analyzing more projects from the BAM and other similar actors in the housing construction industry may provide more quantifiable data. A case study generally aims at understanding concepts and experiences of subjects that are studied and enables a researcher to obtain in-depth insights. For the findings of this study to be transposable to the entire housing construction industry, quantitative research can test and confirm the findings from this study. Combining quantitative and qualitative research methods will provide validity and deepen the understanding on the subject matter. Additionally, research into multiple case studies can be conducted to strengthen the available qualitative data.

Furthermore, to understand what interventions could be done on other levels, different stages and for other actors in the supply chain, additional research that includes researching and interviewing additional actor types can provide insights into this. Examples of these actor types are governmental actors and second tier subcontractors, as well as first tier subcontractors that were not in the scope of this research. Moreover, it is recommended to interview more representatives per organization to gain more insights into the context of the specific organizations and their operations.

Research into the supply chain in other countries, within and outside Europe could provide new or more extensive insights into the topic of implementing sustainability in the supply chain of the housing construction industry. Understanding what barriers and drivers actors from other countries encounter and how they (can) deal with them, will deepen the understanding of the possibilities to enhance the implementation of sustainability in the housing construction supply chain both in the Netherlands and elsewhere.

Additionally, this research found some interesting results concerning co-occurring categories. Most outstanding in this regard is the social and cultural category. This category was found to be one of the least mentioned categories by all actors, but proved to be a recurring category in co-occurrence with other categories. This correlation between categories is important to analyze further in future research, since it is possible that this correlation provides interesting insights into underlying or structural problems (barriers) or opportunities (drivers). This recommendation stretches beyond the social and cultural category, since every category was found to have co-occurring barriers and/or drivers (except for the regulatory and institutional category).

Lastly, this research has formulated a number of recommendations for governmental actors and policy. Further research into this subject is required before applying legislation and other policy measures such as a rewarding system. Focusing on how to implement these measures in the most effective way will be helpful to determine which steps should be taken and in what order to maximize the potential to implement sustainability in the housing construction industry.

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# Appendix A – Barriers and drivers in other industries

*Table A.1 Barriers for implementing SSCM in other industries*

| | | **Car** *Drohom-eretski et al., 2014; Luthra et al., 2011* | **Chemi-cal** *Shohan et al., 2019* | **Manufact-uring** *Gupta et al., 2020; Kiefer et al., 2019* | **Clothing** *Tumpa., 2019* | **Steel** *Orji., 2019; Prasad et al., 2018* | **Construction** *Benachio et al., 2019; Chun et al., 2015; Mathiyazhagan et al., 2018* | **SSCM general** *Khan et al., 2021; Narimissa et al., 2020; Patel & Desai, 2021; Sharma et al., 2021* |
|---|---|---|---|---|---|---|---|---|
| **Economic/ financial** | Uncertainties in market competition | x | | | | | | x |
| | Lack of money to invest (investment is too high) | x | x | x | x | x | x | x |
| **Market/ networking** | Resistance of suppliers to implement certain clean technology practices | x | | | | | | x |
| | Lack of understanding and knowledge on SSCM among organizations in the supply chain | | | x | | | | |
| | No responsibility taken by involved parties | | | x | | | | |
| | Complexity in the supply chain | | | | x | | | |
| | Lack of demand from customers for sustainable products | x | | | x | | | |
| | Lack of promotion of sustain-able products | | | | x | | | |
| | Lack of awareness among stakeholders | | | x | | | x | |
| | Preferences of suppliers/institutional buyers | | x | | | x | | |
| | Insufficient environmental competencies (in market) | | | | | x | | |
| | Wide communication gap (in market) | | | | | x | | x |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Organiza-tional** | Lack of implementing green practices | x | | | | | | |
| | Lack of skilled manpower to implement innovation | | | x | | | | |
| | Uncertainty of innovation process | | | x | | | | |
| | Inability in the organization to align their goals and work on it | | | x | | | | x |
| | Lack of top management commitment | | | | x | x | | x |
| | Insufficient environmental competencies (in organization) | | | | | x | | x |
| | Inadequate proactive plans | | | | | x | | x |
| | Wide communication gap (in organization) | | | | | x | | x |
| | Lack of employee welfare package | | | | | x | | |
| | Lack of worker's training on sustainable operations | | | | | x | | |
| **Regulatory/ institutional** | Lack of government support system | x | | x | x | x | | x |
| | Not enough rules and regulations set by the government | | | x | | | | x |
| | Lack of demand from government for sustainable products | x | | | x | | | x |
| | Lack of awareness among stakeholders | | | x | | | x | |
| | Preferences of suppliers/institutional buyers | | x | | | x | | |
| | Insufficient environmental competencies | | | | | x | | |
| | Wide communication gap (government) | | | | | x | | |
| **Social/ cultural** | Low quality of employees | | | x | | | | x |
| | Wide communication gap (societal) | | | | | x | | x |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Lack of worker's training on sustainable operations | | | | | x | | x |
| **Technolo-gical** | Implications of costs | x | | | | | x | |
| | Inappropriate technology to improve | | | x | | x | | x |
| | Stick with traditional technology | | | x | | | | |
| | Companies cannot measure amount of emissions | | | x | | | | x |
| | Technical obstruction (difficult to work in different way) | | | | x | | | x |
| | Lack of sustainable waste management | | | | | x | | |

*Table A.2 Drivers for implementing SSCM in other industries*

| | | **Car** *Drohomeretski et al., 2014; Luthra et al., 2011* | **Chemi-cal** *Shohan et al., 2019* | **Manufact-uring** *Gupta et al., 2020; Kiefer et al., 2019* | **Clothing** *Tumpa., 2019* | **Steel** *Orji., 2019; Prasad et al., 2018* | **Construction** *Benachio et al., 2019; Chun et al., 2015; Mathiyazhagan et al., 2018* | **SSCM general** *Khan et al., 2021; Narimissa et al., 2020; Patel & Desai, 2021; Sharma et al., 2021* |
|---|---|---|---|---|---|---|---|---|
| **Economic/ financial** | Reduction of costs in supply chain by minimizing consumption of resources | x | | | | | | |
| | Create a market pull | | | x | | | | x |
| | Develop internal financing resources | | | x | | | | |
| | Tax incentive by the government | | | | | | x | x |
| | Look for opportunities in the long run | | | | | x | | |
| **Market/ networking** | Customer awareness and demand for sustainable products | x | x | | | x | x | x |
| | Decrease infrastructure | | | | | | x | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | strain (from market) | | | | | | | |
| | Create environmental collaboration between main and sub-contractor | | | x | | | x | x |
| | Public pressure | | x | | | | x | x |
| | Create awareness among involved parties | | | | | | x | |
| | Public funding | | | x | | | | |
| | Develop collaboration agreements | | | x | | | | X |
| | Develop infrastructure support and facility for sustainable operations | | | | | x | | x |
| **Organizational** | Commitment of top management | x | | | | x | x | x |
| | Improve image of industry | | x | | | | x | |
| | Create sustainable corporate culture | | | x | | | | x |
| | Ensure environmental competencies | | | | | x | | x |
| | Integrating sustainable operations in proactive plans | | | | | x | | x |
| **Regulatory/ institutional** | Support system by the government with regulations and effective legislation | x | | | | x | x | x |
| | Legal requirements | x | | | | | x | x |
| | Tax incentives by government | | | | | | x | x |
| | Create awareness among parties | | | | | | x | x |
| | Develop collaboration agreements | | | x | | | | x |
| | Integrate sustainable operations in proactive plans | | | | | x | | x |
| **Social/ cultural** | Public pressure | | x | | | | x | |
| | Involvement of employees | | x | | | x | | x |
| | Look for opportunities in the long run | | | | | x | | |
| **Technological** | More IT implementation | x | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Information sourcing about green technologies | | | x | | | | x |
| | Create a technology push | | | x | | | | |
| | Access to advanced technology for sustainable operations | | | | | x | | x |
| | Good measurement data | | | | | x | | x |
| | Integrate sustainable waste management | | | | | x | | |

# Appendix B – Interview setup

*Note: this is a translation of the (originally) Dutch interview questions*

1. Introduction
2. Questions to gain a better understanding of the company and role of respondent
3. Barrier and driver category questions
    a. Technological category
        i. To what extent do you think that technology and technological developments have an impact on sustainability processes? You can think of old and new equipment/technology and methods.
        ii. To what extent is there room to implement technological developments that may stimulate sustainability?
    b. Social & cultural category
        i. How important is sustainability in the corporate culture between your company and BAM?
        ii. How (often) are there conversations and discussions about sustainability? To what extent does this topic get priority?
    c. Organizational category
        i. Is there clear corporate policy about sustainability? Is there focus on increasing sustainability in the collaboration?
        ii. What possibilities are there to present your own ideas regarding sustainability?
        iii. What does the corporate policy entail from the main contractor, subcontractor(s) and/or property developer?
    d. Economic & financial category
        i. What role does money play in sustainability?
        ii. To what extent are there sufficient funds for sustainability?
    e. Regulatory & institutional category
        i. What role does the government play in sustainability?
        ii. Is the government facilitating or frustrating your efforts to become more sustainable? Why is this the case?
    f. Market & networking category
        i. To what extent does the construction chain or industry, the market and society value sustainability in your experience?
        ii. Is this facilitating or frustrating sustainability efforts?
    g. Question for the person that works for the internal and the external project: to what extent is there a difference between projects that are internally and externally developed regarding sustainability?
        i. For example, is it the case that there are more opportunities for sustainability in internally developed projects?

# Appendix C – Full list of practical recommendations

**Category 1: Economic and financial**

Subcontractors

- Aim at sharing financial burdens as much as possible with the main contractor when investing in new sustainable operations.
- Stipulate and showcase the advantage of sustainability and sustainable products that you wish to sell or implement.
- Strengthen the construction process with regard to limiting costs of failure to ensure more financial space for the implementation of sustainable operations.

Main contractors

- Aim at sharing financial burdens as much as possible with subcontractors when investing in new sustainable operations.
- Engage and motivate other actors in the housing construction industry to increase their focus on sustainability by increasing the organization's own sustainability efforts and showcasing the benefits thereof.
- Increase sustainable innovation in more expensive housing segments.
- Strengthen the construction process with regard to limiting failing costs to ensure more financial space for the implementation of sustainable operations.

Property developers

- Create and/or strengthen the organization's sustainability strategy towards other actors in the housing construction chain, (there)by engaging and motivating them to increase their focus on sustainability.
- When developing a housing project, try to see where small sustainable options can be used instead of traditional ways: small steps count.

**Category 2: Market and networking**

Subcontractors

- Create awareness, trust and environmental collaboration agreements between the chain actors in the housing construction industry.
- Implement measures to ensure good and timely communication about sustainability requirements and products from the earliest possible stages in the collaboration. This may differ per project, but increased focus on timely (early) communication enables informed decision making in favor of sustainable solutions.
- Establish performance goals with the other chain actors to measure sustainability improvements.
- Increase the presence of sustainability knowledge in the company.

Main contractors

- Create awareness, trust and environmental collaboration agreements between the chain actors in the housing construction industry, thereby enforcing the focus on sustainability between actors.
- Implement measures to ensure good and timely communication about sustainability requirements and products from the earliest stages in the collaboration.
- Establish performance goals with the other chain actors to measure sustainability improvements.
- Ensure that the parties that are included in the chain are willing to work towards sustainability.

- Increase the presence of sustainability knowledge as well as circular and sustainable procurement in the company.
- Work with specialists from the subcontractor(s) to increase knowledge about making products and/or projects more sustainable.
- Share information on sustainability between the property developers, the procurement division and the knowledge division of the main contractor.
- Implement work processes and policy on how to preserve knowledge about sustainable operations and alternatives so other projects can build upon.

Property developers

- Create awareness, trust and environmental collaboration agreements between the chain actors in the housing construction industry.
- Implement measures to ensure good and timely communication about sustainability requirements and products from the earliest stages in the collaboration.
- Establish performance goals with the other chain actors to measure sustainability improvements.
- Increase the presence of sustainability knowledge in the company.
- Employ a sustainability architect for housing construction projects.
- Implement work processes and policy on how to preserve knowledge about sustainable operations and alternatives so other projects can build upon.

**Category 3: Organizational**
Based on this interpretation of the organizational category, the following recommendations are given, specified per actor type.

Subcontractors

- Commitment from top management on sustainability. This includes ensuring that top management values collaboration with trustworthy, sustainability-oriented parties over other possible partners.
- Enhance a sustainable corporate culture/identity.
- Propagate this sustainable corporate culture, thus inspiring employees and create support within the organization to become more sustainable.
- Train and educate employees on choosing sustainable methods.

Main contractors

- Commitment from top management on sustainability. This includes ensuring that top management values collaboration with trustworthy, sustainability-oriented parties over other possible partners.
- Enhance a sustainable corporate culture/identity.
- Propagate this sustainable corporate culture, thus inspiring employees and create support within the organization to become more sustainable.
- Train and educate employees on choosing sustainable methods.
- Ensure a safe environment where (young) employees can inspire each other surrounding the sustainability topic and bring ideas and suggestions to (top) management.

Property developer

- Commitment from top management on sustainability. This includes ensuring that top management values collaboration with trustworthy, sustainability-oriented parties over other possible partners.
- Enhance a sustainable corporate culture/identity.

- Propagate this sustainable corporate culture, thus inspiring employees and create support within the organization to become more sustainable.
- Train and educate employees on choosing sustainable methods.
- Ensure a safe environment where (young) employees can inspire each other surrounding the sustainability topic and bring ideas and suggestions to (top) management.

**Category 4: Regulatory and institutional**

For this category, recommendations are made for the government, since they are responsible for steering both the (housing) construction industry and society as a whole towards a more sustainable future. Since the housing construction actors are heavily dependent on the legislation set by the government, the approach towards more sustainable operations should be an integrated approach that includes the government.

- Ensure legislation does not contradict with other parts of legislation and is unambiguously formulated.
- Draft a long term vision and translate this into policy that is predictable in the steps that organizations in the housing construction chain are required to take. These steps should therefore provide a clear and realistic timeline for organizations so they know what they should adhere to without question.
- Run campaigns towards organizations using positive language that encourages people to feel like they can actively contribute to working towards a solution to a problem. Legislation is coercive in nature, but that does not mean communication should be negative and restrictive as well.
- Use positive reinforcement measures such as bonus points and (tax) incentives for organizations when they are working towards more sustainable operations. On the other hand, use negative reinforcement measures such as increased taxes or other penalties when they emit too much emissions.
- Develop and provide (templates of) collaboration agreements.

**Category 5: Social and cultural**

Based on this interpretation of the social and cultural category, the following recommendations are given. In this case, all recommendations apply to every actor type (subcontractors, main contractors and property developers). Therefore, the recommendations are not specified per actor type.

- Involve employees in increasing sustainability in housing construction processes.
- Include and focus on sustainability in the corporate culture.
- Create a corporate culture where employees feel responsible and engaged in increasing sustainability in housing construction processes.
- Adopt an open attitude towards new ideas from external parties as well as from (internal) employees.
- Pay attention to public opinion towards sustainability and use the momentum gained from public attention for sustainability.

**Category 6: Technological**

<u>Subcontractors</u>

- Gain access to advanced technology (information) to increase chances to implement sustainable operations. This can be done by consulting technological universities and other research institutions.

- Hire an external expert to assess the organization's sustainable performance from a technological perspective to avoid assessing your own efforts which can increase the chance of ignoring blind spots.
- Invest time and money into creating more sustainable production methods, such as extending the drying period of concrete to decrease the use of cement.
- Investigate ways to use more prefabricated materials to ensure transport flows are more efficient and to find ways to limit emissions on the construction site.
- Reuse energy and materials where possible during the production process.
- Employ electrical ways of transport.

Main contractors

- Invest in facilitating adequate electrical infrastructure on construction sites, so electric machinery can operate.
- Install a central communication point for employees to find the correct and most updated information available within the organization regarding technical knowledge and experience.
- Experiment with the implementation of sustainable solutions by building on a small scale.
- Gain access to advanced technology (information) to increase chances to implement sustainable operations. This can be done by consulting technological universities.
- Hire an external expert to assess the organization's sustainable performance from a technological perspective.
- Invest time and money into creating more sustainable production methods, such as extending the drying period of concrete to decrease the use of cement.
- Investigate ways to use more prefabricated materials to ensure transport flows are more efficient and to find ways to limit emissions on the construction site.
- Reuse energy and materials where possible during the production process.
- Employ electrical ways of transport.

Property developer

- Gain access to advanced technology (information) to increase chances to implement sustainable operations. This can be done by consulting technological universities.
- Hire an external expert to assess the organization's sustainable performance from a technological perspective.
- Standardize the choice for more sustainable options within the design and development of housing project.