UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Master's Thesis

Innovation Adoption for Eco Materials in the Construction Industry in Sweden:

How Three Players Can Actively Foster the Adoption Process

A Case Study on the Material Hempcrete
with the Company House of Hemp

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Abstract

The construction industry is currently experiencing environmental problems associated with greenhouse gas emissions, in particular due to the extensive use of unsustainable materials. In this regard, the industry is in need of alternative solutions, one of which is the introduction of innovative green materials. However, the number of adopted new innovations in the market is low. If the material is considered innovative and new to the market, then it may experience challenges in the process of adoption by potential users, which can negatively affect its diffusion in the market.

This Master's Thesis provides an insight to the adoption process of eco materials in the Swedish construction industry. An overall objective of the research was to study how the whole process of adopting a new green material can be fostered. This was achieved through examining the barriers of the innovation adoption process, as well as finding solutions that can help to overcome these barriers that prevent the adoption of new materials. Furthermore, the authors redesigned Rogers' (Rogers, 2003, m, Rhein, 2021, o) innovation adoption stages model to make it most relevant for the Swedish construction industry.

The authors performed a detailed research of the available literature on the subject related information. The thesis provides a detailed view of the overall classification of innovation, innovation diffusion process, drivers of innovation and innovation in the construction industry. For the primary data collection, interviews were conducted with respondents who work in the construction industry in Sweden or carry out research in relation to this sector. The secondary data consists of relevant sources such as databases, statistics and newspaper articles. The analysis was performed with a thematic approach by identifying codes and themes.

The main findings of this research show how different players can accelerate and push forward the innovation adoption process with certain actions in order to overcome the identified barriers currently blocking the adoption process. The responsible performers of these actions were categorized in three different groups: innovation adopters, suppliers and the government. Additionally, conditions were identified that ensure a supportive environment for the adoption of innovation. The results not only give new insights into the innovation adoption process of green innovative materials that can serve as a foundation for future research, but also inspire the affected people to act and contribute to a more innovative and green construction industry.

***Key words**: Swedish construction industry, innovation adoption, hempcrete, eco material*

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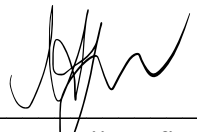

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1. Introduction

1.1 The Construction Industry

The construction industry plays a significant role in the EU economy as the industry represents 9% of the EU's GDP and provides 18 million job places (European Commission, 2021). That is also reflected by Sweden, where the sector represents a growing source for employment. The number of employed people in the industry increased by 26.8% throughout of 2010-2019 to 679,186 (European Commission, 2020). The overall revenue of the construction of buildings in Sweden amounted to 33.94 billion U.S. dollars in 2018 and is forecasted to grow to 37.56 billion U.S. dollars by 2024 (Zendehrouhkermani, 2020).

In the industry, there are multiple different companies involved. In 2019, the Swedish construction sector consisted of 177,367 enterprises in total. 53.7% are part of the narrow construction sub-sector (only including on-site work), 23.8% are real estate activities, 19.7% architectural and engineering activities and the last group with 2.9% is represented in the manufacturing sub-sectors (European Commission, 2020). Looking at the structure of the industry in Sweden, it can be observed that it is dominated by the three biggest construction firms *Peab*, *Skanska* and *NCC* (De Best R. , 2021).

1.1.1 Environmental Issues

Observing the industry from an environmental side, it gets clear that the sector faces a lot of challenges. In 2019, the building construction industry including materials and construction processes accounted for 10% of the total worldwide CO2 emissions. Adding the CO2 emissions that result from the operation of buildings, the number rises to a total of 38% (United Nations Environment Programme, 2020). It also has to be highlighted that materials play a decisive role. Concrete is by far the biggest CO2 contributor. The material accounts for 8% of the total greenhouse gas emissions in 2015 and will have increased to 12% by 2060 (OECD, 2019).

But not only the greenhouse gas emissions constitute a problem, but also the actual amount of material that is used. Again, concrete is used to serve as an example. On a global level, the yearly consumption of concrete is 10 billion tonnes which is after water on the second place among most widely used materials globally (Walkley, 2020); (Watts, 2019). For the production of concrete 9% of the global industrial water is used and a certain type of sand is required which leads to the deconstruction of lakes, beaches and riverbeds (Miller, Horvath, & Monteiro, 2018); (Beiser, 2017).

1.1.2 Swedish Innovativeness

When it comes to innovation, it can be highlighted that Sweden is considered the leader in the construction industry of the *European Union*. The country performs the best in the following categories: lifelong learning, international scientific co-publications, new doctorate graduates, public-private co-publications, R&D and innovation expenditure and patent applications. But regarding the innovation performance, the sales of new-to-market or new-to-firm product innovations, the enterprises providing ICT training and venture capital expenditure are especially weak in Sweden (European Innovation Scoreboard, 2020). In summary, it can be stated that there are new innovations developed, but not successfully adopted, even though the need for new innovations to reduce the negative environmental impact is present. That could indicate that the adoption of new innovations is slow or that there are barriers blocking the successful innovation adoption process. All of that will be investigated closer in the analyses.

1.2 Literature Gap

Looking at the adoption process from a theoretical point of view, multiple different papers could be found dealing with that theory. Current literature extensively discusses how companies that introduce innovative products or services go through the stages of development, from idea generation to commercialization. Geoffrey Moore (2014) was the first to argue that when an innovation enters the market, there is a chasm between the early market (which adopts innovation first) and the mainstream market. Moore (2014) provides guidance on how the companies can cross this chasm and adapt the product, Rackham (1998) explains why new products that show a great demand eventually fail. Some papers are about the consumer's resistance to innovation and the reasons behind it (e.g. (Talke & Heidenreich, 2013); (Kleijnen, Lee, & Wetzels, 2009); (Laukkanen , Sinkkonen, & Laukkanen , 2008). One can also find information about the strategies to improve new product adoption (e.g. (Eng & Quaia, 2008); (Rogers, 2003); (Kohli & Jaworksi, 1990). There are also research studies that were based within the construction industry focusing on innovation diffusion regarding home building and its influencing factors (Blackley & Shepard , 1996); (Toole, 1998) or regarding a specific technology (Islam, 2014); (Koebel, McCoy, Sanderford, Franck, & Keefe, 2015).

Even though researchers covered a lot of subject areas, it can be argued that the current theory cannot be fully applicable to the adoption of construction materials in Sweden because of the following reasons: (1) current literature does not touch upon the construction industry, but mainly focuses on high-tech innovations and technology industries; (2) the presented studies in the literature were carried out in other countries where market conditions are very different to Sweden (e.g. most studies mentioned in the literature were done in the USA). Markets vary by such important aspects as local regulations (for example, it was decided to authorize the

cultivation of industrial hemp in Sweden in 2003, while in certain other countries a similar law was adopted earlier (Sveriges Riksdag, 2004), consumer needs and preferences, innovation rates, and in general by market trends in various industries; (3) the last point is about questioning the relevance of the literature as a lot of papers were published 20 or more years ago. Since then, the environment has changed a lot. For instance, with the internet, a lot of conditions like the access to information or communication facilitated which has an effect on innovation diffusion and product adoption strategies.

1.3 Objective of the Study

In the Swedish construction industry, there is a strong need for new innovative eco-solutions to improve environmental health and lower the negative impact on the environment. As Sweden is known to be the innovation leader in Europe, but at the same time shows a low innovation adoption rate, the efficiency of the adoption process has to be questioned. Consequently, the researchers of this study wanted to investigate how the whole process of adopting a new natural construction material can be fostered and accelerated. In this context, the barriers that negatively influence the process are examined and solutions are found of how these can be eliminated or mitigated. The research question and the two sub-questions helping to answer it are defined as follows:

***RQ**: How can the innovation adoption process of eco materials in the Swedish construction industry be fostered?*

> ***RQ a**: What are the barriers that influence the adoption process of new eco innovative materials?*
>
> ***RQ b**: How can the barriers of the adoption process of new eco innovative materials be overcome?*

1.4 Company Cooperation

In order to answer the research questions and gain decisive and valuable insights, the authors cooperated with the company *House of Hemp*. The start-up started selling its products in Gothenburg in 2018 as a subsidiary of the French company *BCB-Tradical* - a company providing various kinds of lime solutions (BCB Tradical, 2021). *House of Hemp* offers educational workshops and specializes in the durable insulation material hempcrete, whether it is new construction or renovation projects. Hempcrete is a green and eco-friendly material

consisting of hemp, lime and water and serves as an example in this research for a new innovative product.

1.5 Disposition

The thesis is structured in the following manner: First, a case description regarding construction materials and potential adopters, the regulation system in Sweden, product assessment techniques, the increasing awareness towards the environmental issue and the material hempcrete is provided. The literature review represents the second chapter and gives an overview regarding relevant theories necessary in order to understand the concept and background of the research study consisting of the innovation diffusion and innovation adoption process, also concerning the construction industry. Thirdly, the methodology is discussed including the strategy and design that were followed, methods used to collect and analyse the data, the quality and limitations of the study. The subsequent chapters are about the initial findings of the research, the final analysis, where the results are presented followed by the conclusion including theoretical and practical contributions that were made by the two authors.

1.6 Delimitation

For the purpose of achieving more definitive results, the authors delimited the thesis to the investigation of the adoption of innovative eco materials in the construction industry. Likewise, this research is directed to the examination of the Swedish market only, which allowed the authors to sufficiently explore the conditions of the given market and apply it to the results afterwards. Consequently, the interviewees that participated in primary data collection were selected according to strict criteria in order to have a diverse group of contributors. Furthermore, hempcrete was chosen to serve as the practical example of a construction material, as the material is new to the market and has a lot of environmental-friendly characteristics which will be discussed in the next chapter, among other things.

2. Case Description

The purpose of the following sections is to give an overview of background information relevant to comprehend the study. The topics refer to the construction materials and potential adopters, the regulation system in Sweden, product assessment techniques, the increasing awareness towards the environmental issue and finally, important information regarding the material hempcrete.

2.1 Construction Materials

As hempcrete is a material used to construct buildings, construction materials have to be observed more closely. There are a lot of different types of materials that are commonly used to construct buildings: cement, steel, glass, sand, gravel, clay, concrete, marble, timber and wood. The latter two are put into the category naturally occurring, whereas the rest are man-made materials. The choice of material directly influences the endurance and the life of a building. When deciding on them, not only the economic costs but also the costs resulting from pollution and energy and the social factors have to be taken into consideration. In addition to that, with constantly new building standards, the reality of climate change and the increasingly frequent natural catastrophes, the demand for stronger, more durable, more reliable and greener building materials is increasing (De Best R. , Statista, 2020); (De Best R. , Statista, 2021); (De Best R. , Statista, 2020). Looking at the future development of the global construction material industry, high growth is predicted. The market is estimated to increase by 0.5 trillion U.S. dollars in seven years reaching 1.5 trillion U.S. dollars by 2027. That complies with an annual growth rate of 5.6% (Global Industry Analysts, Inc, 2020).

2.2 Potential Adopters

As the industry is heterogeneous and consists of a complex system, multiple different actors are involved in the industry. The study focuses on the adoption process of construction materials, which is why only the players that are involved in the adoption and implementation process of new materials are described in the following. Those include not only people having jobs in architectural practice, construction, engineering, real estate and consulting companies and municipalities, but also the customer. The roles and also the specific jobs involved can differ depending on the project and building contract. The building owner, which can be a private, public or corporate customer, has the role to initiate and monitor the project and make final decisions. Architects are the ones who design and draft the building. Engineers check the practicability of the design and are responsible for the static calculations. Project managers plan, guide and watch the project along the process. The consultants can include the roles of

the latter three. They are advising the building owner in making decisions and can participate in the project from its initiation to the very end. And finally, the construction workers are at the construction site building the construction.

2.3 Regulations in Sweden

Sweden has certain regulations that must be followed during the construction process. These regulations are published by the National Board of Housing, Building and Planning (*Boverket*), which is an administrative authority working primarily with the developments in the areas of housing, building and planning and which belongs to the Swedish Ministry of Finance (Boverket, 2020). Not all regulations published by *Boverket* are mandatory. For example, general recommendations are provided as a part of regulations and they can help comply with binding regulations. The binding regulations include acts, ordinances and mandatory provisions. In the Swedish regulatory hierarchy, the acts are being adopted by the parliament, the ordinances are being adopted by the government, and mandatory provisions and general recommendations are drafted by *Boverket*. Since Sweden is part of the European Union, EU directives and EU regulations also have an impact on the Swedish legislation and are taken into account when drafting regulations in Sweden (Boverket, 2018). The areas that are addressed in the regulations include general rules for buildings, accessibility, room height, utility rooms, mechanical resistance and stability, safety in case of fire, hygiene, health and environment, protection against noise, safety in use, energy management. They also comprise design guidelines concerning areas such as requirements for fire resistance, timber, masonry, concrete, steel and aluminium, geographical and load-bearing structures (European Commission, 2020).

While the current regulations specified by *Boverket* barely cover the environmental aspects, there is also a Swedish Environmental Code, which applies to all human actions or measures that may affect the fulfilment of the objectives of the Environmental Code, including actors of the construction industry. The Swedish Environmental Code represents framework legislation that includes general provisions aiming to encourage sustainable development. The goal of the Environmental Code is to establish a healthy environment for all inhabitants in Sweden (Swedish Environmental Protection Agency, 2020).

2.4 Certificates and Databases

The following assessment possibilities play a decisive role in the adoption process of new innovative materials which will later be shown in the findings and analysis. There is a certification system in Sweden offering multiple environment certificates and official databases. Latter offer a list of tested, assessed and evaluated products and materials. *SundaHus*

is a company and a member of *Sweden Green Building Council* (*SGBC*) that offers a database with multiple types of tested products (SundaHus, 2021). *BASTA* is a freely accessible database listing all construction products that meet the strict requirements regarding substances (BASTA, 2021).

The purpose of certificates is the assessment of the environmental performance of for instance a building, infrastructure, project, product or material by a third party. The most common ones in Sweden include *BREEAM-SE, NollCO2, Miljöbyggnad, City Lab, LEED, CEEQUAL, GreenBuilding, Environmental Product Declaration (EPD), Swan Ecolabel* and *EU Ecolabel* (Boverket, 2021). Some of them were exclusively developed for the construction industry, others offer a label for multiple product categories from several different industries. As these labels are voluntary, it is a way for companies to demonstrate their effort to contribute to a more sustainable and climate-neutral industry.

The non-profit organisation *Ecolabelling Sweden* is responsible for the Swan Ecolabel – *Svanen* (Svanen, 2021). The certificate which is valid in the Nordic countries determines requirements regarding good indoor climate, good ventilation, building process, energy efficiency and materials (Nordic Ecolabel, 2021). The *EU Ecolabel* focuses on the assessment of the whole life cycle of a product based on multiple different criteria (EU Ecolabel, 2021). The administration of the first seven certificates which were listed in the previous section is done by the non-profit organisation *SGBC*. *BREEAM-SE*, developed in the United Kingdom, is one of the oldest certificates and internationally accepted. It assigns grade levels to new buildings based on different factors like energy use, water and project management. *NollCO2* addresses greenhouse gas emissions and makes sure the certified buildings have a net-zero climate impact. *Miljöbyggnad* assesses factors like energy consumption, building materials with 16 different values. The action plan including project planning and process management can be certified with the *City Lab Action Certification* if certain sustainability indicators are valid. *LEED* is a global certification system that awards four different types depending on the points achieved. The categories include energy and water consumption, indoor environment, materials, innovation strategies and more. *CEEQUAL*, developed by the British BRE, assesses projects depending on eight different criteria. In order to get a *GreenBuilding* certification, the building needs to decrease its energy consumption by 25% (SGBC, 2021). The *EPD* is an international certificate that includes the whole life cycle assessment of products. The goal is to offer objective, comparable and transparent information regarding the environmental impact (Environdec, 2021).

2.5 Awareness towards Environment Issues

As it has been described in the introduction, the industry is responsible for a huge part of the worldwide CO2 emissions and waste management. Consequently, the need for a change is obvious and is becoming more evident which is also reflected by different indicators. The first one is about the market growth for green building materials. In 2018, the market was valued at 223 billion U.S. dollars and is estimated to increase to a total of 433 billion U.S. dollars by 2024 (De Best R. , 2018). Another indicator is represented by new set goals and multiple newly adopted frameworks and regulations. The UN has formulated a strategy specifically targeting the construction industry. There are five different fields that the UN has put in the centre of future development: net-zero buildings, material and circular economy, nature-based solutions, health and wellbeing, cooling for resilience and adaptation (United Nations Environment Programme, 2020). The green deal is another action plan that was initiated by the EU in 2019. It contains the goal of becoming the first climate-neutral continent on earth (Europäische Kommission, 2021). A further example is the Paris Agreement which was initiated by the United Nations (UN). It was signed by 196 parties and became effective in November 2016. The agreement unites multiple nations fighting for the same goal: a climate neutral world. The target is to limit global warming at least below 2.0 degrees Celsius, ideally below 1.5 degrees Celsius. For that, greenhouse gas emissions have to be decreased (United Nations Climate Change, 2021).

Sweden is also a part of the Paris Agreement, which is why in 2017, the country has introduced a new climate policy framework. In the long term, Sweden is aiming for zero net greenhouse gas emissions by 2045 (Allerup, 2020). Another approach is to initiate a new regulation. The Swedish government is planning to establish a new climate declaration for the construction of new buildings by the 1st of January 2022. That entails the submission of the declaration by the developer which contains the climate impact. The goal is to develop deeper knowledge regarding the climate impact and the life cycle of buildings. The calculations consider the material winning, manufacturing of products, work at the construction site and transportation (Boverket, 2021). Those introductions are not only happening on a national, but also on a local level. Gothenburg, the second largest city in Sweden has established a climate strategic program with the goal to decrease greenhouse gas emissions until they are on a sustainable level by 2050 (Göteborgs Stad, 2021). All of that highlights that the awareness towards the climate impact is increasing. That condition, as the results will show, play a significant role in the adoption process.

2.6 Overview of Hempcrete

The following sections provide an overview of the material hempcrete, and discuss its history, characteristics, how it is used and applied, why it is considered an innovation and where it currently stands in the Swedish market.

2.6.1 History

With the development of the construction industry, the technologies used when building, the introduction of design rules and changes in constructing traditions in general, starting from the 1980s, builders proceeded to explore new elements and compositions to improve existing techniques or replace them (Amziane & Arnaud, 2013). As a result, during these years, hempcrete was developed in France, which primarily served as a solution to the problem of previous materials, which retained moisture inside the construction and thereby causing damage to the buildings made of wood. The use of hempcrete began to gain wide attention in France followed by Europe and is currently most commonly used in France, the UK, Canada, Australia and South Africa (Stanwix & Sparrow, 2014).

2.6.2 Application and Characteristics

Hempcrete is a man-made and bio-based construction material that consists of hemp shives, lime binder and water (Bedliva & Isaacs, 2014). Collet & Pretot (2014) identify three methods of hempcrete production: (1) *the spraying method* - the dry mix of hemp shives and lime-based binder is blown through the pipe with a stream of compressed air, the water is added later; (2) *moulding method* - the form is filled with a mixture hemp shives and lime-based binder, adding the required amount of water; and (3) *precasting method* - an industrial process in which the blocks are made by pouring into a mould the blend of the slaked lime with the hydraulic lime and hemp shives.

Hempcrete is used to create different surfaces for building constructions. It is mainly applied for the creation of walls, roof and floor (Amziane & Arnaud, 2013), serving as a green, ‘breathable’ and insulating material. Today, hempcrete is mostly used as the main natural alternative to cement-based concrete (Bedliva & Isaacs, 2014). Hempcrete by itself is not a strong enough material to handle the pressure from the roof and upper floors, therefore it is poured into a framework or built around it which is shown in Figure 1 (Stanwix & Sparrow, 2014). The load-bearing framework is usually made out of timber, metal, as well as other materials. Depending on the needs of the project, this framework can be embedded or offset inside or outside (Lhoist Southern Europe BCB, 2016).

One of the most important qualities of hempcrete is that it has various environmental characteristics. The lifecycle of hempcrete is highly effective in combating environmental issues such as the exhaustion of natural resources, water and air pollution (Lhoist Southern Europe BCB, 2016). Hempcrete is produced from renewable resources, it is recyclable, and its production requires less energy than the production of concrete from cement, and most importantly, it has negative greenhouse gas emissions (Bedliva & Isaacs, 2014). Hemp absorbs 1.7 times its dry weight of CO2 and a 300 mm thick hempcrete wall emits minus 31 kg per meter. The ability of this material to absorb CO2 compensates for the emissions of this gas from the production of hempcrete (Woolley, 2013).

Figure 1: The process of polishing a hempcrete wall. Adopted from Peter Holmdahl (2021)

Besides being a very green material, hempcrete has many other properties that help to compete with other materials. Stanwix & Sparrow (2014) outlined these qualities in their book: (1) *Mechanical behaviour* - hempcrete has a high porosity, which enables flexibility, and gives such characteristics as lightness, absorbency, and heat resistance; (2) *structural qualities* - as an element of the structural frame of the building, hempcrete provides strength, which significantly reduces the likelihood of lateral displacement, the amount of wood used and construction time for making a frame; (3) *fire resistance* - hempcrete is hard to set on fire as it is declared as “non-flammable material”, and moreover, its fire resistance improves over time; (4) *vapour permeability and hygroscopicity* - these properties help to prevent the occurrence of condensation and, as a result, to avoid mould, and also improve the quality of indoor air; (5) *resistance to damage by moisture* - since hempcrete is an organic material, unlike synthetic ones, it can absorb and desorb moisture indefinitely, without negative consequences; (6) *thermal performance* - vapour permeability and hygroscopicity directly affects the thermal

performance on hempcrete, they help maintain a constant temperature inside the building, thus reducing the need for heating or cooling indoor air; (7) *acoustic performance* - it is a very effective material for sound insulation, where the porosity of hempcrete again plays an important role; (8) *toxicity and indoor air quality* - hempcrete does not pose any risk of release of toxic substances, and the ability to regulate air humidity provides quality air and prevents the emergence of harmful bacteria.

2.6.3 Categorisation

The researchers categorize hempcrete as an eco, innovative material. First of all, the term green will be substituted with the notions green and environmental as it is common among researchers (Schiederig, Tietze, & Herstatt, 2011). Furthermore, hempcrete can be defined as an eco-innovation as the material fits the following definition which is based on the *OECD* definition of innovation:

> *"the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives"* (Kemp & Pearson, 2007, p. 7)

In addition to that, the material is considered an innovation on the Swedish market because, according to Rogers (2003) and Dearing & Cox (2018), innovation is something that is perceived as novel by an adopter. Hempcrete in the Swedish market is rather unknown and hardly ever used in the construction industry. Mostly the use of hempcrete can be seen in private projects, for example when someone wants to build their own house. The material is therefore considered an innovation for the actors of the construction industry in Sweden.

It is also important to highlight that hempcrete is a low-tech product. Cambridge University Press (2021) defines low-tech as "technology using simple tools and unsophisticated equipment and methods" and it is the opposite of high-tech. Hempcrete is not difficult to apply and the process is completely carried out and controlled by a human. Also, the material itself consists of natural and simple materials.

When it comes to the typology of innovation, it can be said that this study focuses on radical architectural innovations. Referring to the examples that were provided by Slaughter (1998), due to the fact that a new industry emerges (manufacturing and fabrication) and the system including new linkages (new suppliers) changes, the authors define hempcrete as a radical

innovation. Reflecting on the model of construction innovation introduced by Slaughter (1998), architectural innovations match the characteristics of hempcrete, as the material requires a lot of change. As Slaughter (1998) points out, the users of architectural innovation need to know and understand all the changes in order for the innovation to succeed. In this case, the changes involve all players in the industry. It means new types of calculations will have to be made (engineer), the characteristics like optics have to be considered (architect), the way of building is different as new machines need to be used (construction worker) and to measure the climate impact further calculations have to be carried out (e.g. innovation manager). That requires a lot of knowledge gain, but also knowledge transfer between the players.

2.6.4 Hempcrete in Sweden

By conducting research, the authors of this thesis determined three companies from Sweden that are engaged in the distribution and application of hempcrete, these companies are *Biobyggarna, Ekolution* and *House of Hemp*. No official data was found on the rate of uses of this material in Sweden. As well as at the moment, hempcrete in Sweden does not have any local certifications and is not listed in local official databases. However, hempcrete is gradually gaining popularity in Sweden and more and more industry participants are showing interest in it. For example, this year the company *House of Hemp* won a bid to help build a complementary building for Sweden's first fossil-free construction project - “Hoppet”, initiated by the city of Gothenburg (Göteborgs Stad, 2021). The development of the hemp industry can also be facilitated by the fact that in 2013, the European Court of Justice decided to lift the Swedish ban on the cultivation of industrial hemp and therefore the cultivation of verified species of hemp in Sweden has become legal again, with permission of the Swedish Board of Agriculture (Sveriges Riksdag, 2004).

Figure 2: Hempcrete house in Sweden. Adopted from Peter Holmdahl (2021)

3. Literature Review

The literature review gives an overview of the most relevant concepts and theories necessary to understand the research study. The first part talks about innovations in general and the diffusion model including the decision process and the chasm. Subsequently, the role of innovation in the construction industry is discussed.

3.1 Overview and Classification of Innovation

Multiple different authors have been dealing with the topic of innovation for several decades. The results are analyses of innovation from different perspectives. Not only definitions have been developed, but also attributes, typologies, classification schemes and characteristics which will be discussed in the following.

Baregheh, Rowley, & Sambrook (2009) collected 60 different definitions of innovation from interdisciplinary literature and concluded with a universal version:

> *"Innovation is the multi-stage process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace."* (Baregheh, Rowley, & Sambrook, 2009, p. 1334)

The authors also present attributes in order to capture innovation. The first one is about the nature which differs between new and improved innovation. The second one refers to the output of innovation i.e. a product or a service. Another attribute is about the different phases of innovation starting with the idea and ending with the commercialization. Social context addresses people, entities or systems that are a part or influencing factors of the process of innovation. Resources also play a role when it comes to innovation and the last attribute talks about the goal of innovation that wants to be achieved.

Other researchers have identified typologies of innovation (Christensen, Anthony, & Roth, 2004). The first differentiation that can be made is about innovation being sustaining or disruptive. Sustaining innovation means improving products, services or processes regarding cost, performance, quality or/and safety and introducing them to established markets. Those can be classified as either incremental, radical or a displacement. The latter means the innovation is directed at a certain point in the value chain of an industry. If that is not the case, the innovation is either incremental or radical. Radical innovation has a more drastic and unpredictable influence and leads clearly to a change in the industry and often to the entrance

of new companies in the industry. Incremental innovations on the other hand are less impactful and appear on a constant basis. Disruption, which was first introduced by Clayton M. Christensen, addresses an innovation with a new value proposition that transforms the industry and sometimes creates a completely new market (Christensen, Anthony, & Roth, 2004) (Slaughter, 1998). An overview of the different types is provided in Figure 3.

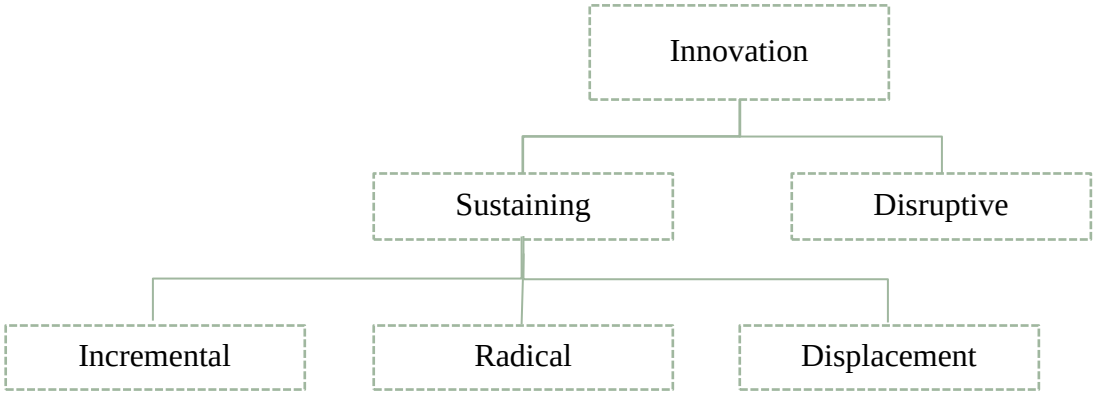

Figure 3: Different types of innovation, compiled by the authors

Moore (2014) points out the classification of innovation in terms of its level of change. Discontinuous innovation requires behavioural change or an alteration of other products and services, whereas continuous innovation does not expect any changes in behaviour.

Another way to analyse innovation is to look at it from the perspective of adopters. Rogers (2003) proposes attributes of innovation perceived by potential adopters. These attributes are relative advantage, compatibility, complexity, trialability, and observability (see Table 1) and also play a role when it comes to innovation adoption and have an impact on the rate of adoption of innovation which will be discussed in the next section.

Innovation characteristics	Description
Relative advantage	Extent to which the innovation is perceived as better than idea it succeeds (perceived net benefit)
Compatibility	Extent to which the innovation conforms to existing values, behaviours and requirements of potential adopters
Complexity	Extent to which the innovation is perceived to be difficult to understand and implement
Trialability	Extent to which the innovation may be tested on a trial basis

Observability	Extent to which the innovations outcomes are visible to others

Table 1: Characteristics of innovations (based on Rogers, 2003). Adopted from Rhein (2021, page 40)

3.2 Innovation Diffusion Model

There are six different stages in the development process of innovation. Firstly, a problem or need is identified, then basic and applied research needs to be done. After that, the development and commercialization phase takes over, followed by the diffusion and adoption process, ending with consequences (Rogers, 2003). For this research study, the focus is on the fifth stage. In order to understand the factors influencing the spread of innovations, one should turn to the innovation diffusion process (Wejnert, 2002). Rogers (2003, p. 6) suggests the innovation diffusion model that explains how innovations are spread among different groups of adopters, and he identifies the innovation diffusion process as "the process in which an innovation is communicated through certain channels over time among the members of a social system". Thus, this process consists of four main elements. While the *innovation* is separately discussed in detail in the previous section, the remaining three elements are explained further.

Communication channel is the means which individuals use to communicate with each other. Communication in this context means a process in which two or more individuals exchange information concerning innovation or new ideas. The communication process typically involves four actors: (1) an innovation, (2) an individual or any other actor who has a knowledge of innovation or experience using it, (3) another individual or actor who does not have knowledge about or experience with innovation and (4) a communication channel that connects the last two mentioned actors. The third element of innovation diffusion is *time*, which can be affected by (1) *the innovation-decision process*, in which the adopter passes from acquiring the first knowledge about the innovation and forming the attitude towards it to the final decision whether to use it (see Figure 4); (2) *the innovativeness* of an adopter, which determines how early the adapter accepts innovation compared to other participants in the social system thereby dividing adapters into the following groups that will be further examined below: innovators, early adopters, early majority, late majority, and laggards; and (3) an innovation's *rate of adoption*, identified as the speed at which the group of actors of the social system adopts the innovation and it is measured by the timeframe required for a certain percentage of actors to adopt the innovation. The last element of the innovation diffusion process is *a social system*, defined as a set of actors who interact to solve a common problem and achieve a mutual goal. All actors in the system are different in their behaviour, hence, the system is supplemented by a formal structure, established by the relationships between the actors and consisting of hierarchical positions (Rogers, 2003).

3.2.1 The Innovation-Decision Process

The innovation-decision process plays a significant role in this study and helps to answer the research question. Therefore, it is extensively explained in the following section. Rogers (2003) describes it as the process during which the adopter (the decision-maker) passes through the whole path of interaction with the innovation, from the beginning, where the adopter learns about new innovation, to the end, where the adopter implements it or decides not to use it. The innovation-decision process can be divided into five main steps, which are shown in Figure 4.

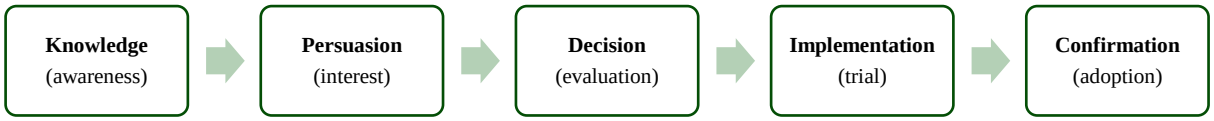

Figure 4: Stages of adoption according to Rogers (2003) and in brackets the terms Rogers used previously, in his 1962 edition. Adopted from Rhein (Rhein, 2021, p. 39)

The initial step is *knowledge*, where the adopter for the first time receives information about new innovation and a superficial understanding of its functions. After getting acquainted with the innovation, the adopter forms either a favourable or unfavourable attitude towards it, this stage called *persuasion*. This is followed by a *decision* phase, at which the adopter makes the final decision to adopt the innovation or reject it. Finding more information about the innovation, reducing uncertainty, and gaining a more comprehensive understanding of the merits and demerits of innovation helps the adopter make a decision. Subsequently, *implementation* occurs when the innovation is applied and used. Finally, *confirmation* takes place when the adopter seeks reinforcement of an already made decision of innovation adoption (Rogers, 2003).

Although Rogers (2003) identifies five main steps of the innovation-decision process, he also notes two other scenarios. The discontinuance may appear if the adopter becomes dissatisfied with the innovation, or if a better or more suitable alternative was developed. As a consequence, the innovation is rejected even after it has been implemented. Furthermore, later adoption can happen if the adopter changes his decision, and after the rejection of the innovation, chooses to adopt it.

3.2.2 The Chasm

Moore (2014) declares the chasm that separates groups of innovation adopters. The so-called chasm significantly impacts the process of innovation diffusion, and to discuss it, it is essential to give an in-depth examination of different groups of adopters. Adopters have been categorized into groups considering that they have distinct innovation adoption periods (*the*

innovativeness), so they are allocated depending on when they start using the innovation from the moment it becomes available (Rogers, 2003). These groups are defined in Table 2.

Adopter Group	Characteristics
Innovators – Venturesome	- Interested in new ideas, ready to accept occasional setbacks, able to handle a high degree of uncertainty - Control financial resources to soften possible losses from unprofitable innovation - Imports new ideas in the system from outside - Have the ability to understand and apply complex technical knowledge - Sometimes may not be respected by other members of the system
Early adopters – Respect	- Perceived as leaders and role models in most systems, decrease uncertainty about new innovation - Their behaviour can significantly influence and speed up the adoption process of the new idea in the system - Seeks to make prudent decision regarding the adoption of new innovation so as not to lose the respect and trust of other members in the system
Early Majority – Deliberate	- Slightly ahead of the average member of the system, frequently interacts with other members of the system - Serves as a link between those who adopt innovation very early and those who do it relatively late, thus becoming an essential part of the diffusion process - Takes some time to weigh up a new idea before fully implementing it, so their innovation decision-making period is relatively longer than that of innovators and early adopters
Late Majority – Sceptical	- Wait until the most other members of the system adopt innovation, very sceptical and careful towards the implementation of new ideas - The main reasons for adopting innovation are economic necessity and pressure from other members in the system
Laggards – Traditional	- The last to adopt an innovation, isolated from the social networks of other systems, extremely careful when implementing new ideas - Lengthy innovation-decision process, the adoption and use occurs much later than awareness of the new idea - Have limited resources and precarious economic condition

Table 2: The adopters groups compiled by the researchers (Rogers, 2003)

Figure 5 shows the innovation adoption bell curve demonstrating how innovations are being adopted on the market from one type of adopter category to another during the entire lifecycle, and what is the ratio of these categories in the social system (Rogers, 2003). The logic of the innovation adoption lifecycle is based on the fact that innovations are perceived by any social system in stages, in accordance with the psychological and social portraits of various actors of this system. Innovators and early adopters represent the early market, while the rest adopter categories are a part of the mainstream market (Moore G. A., 2014).

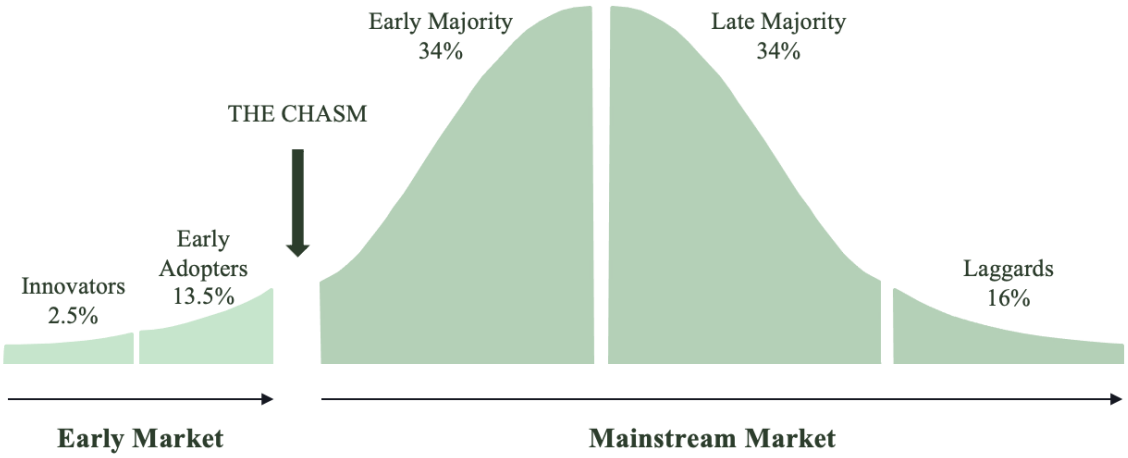

Figure 5: The innovation adoption lifecycle by adopter groups compiled by the researchers (Rogers, 2003), (Moore G. A., 2014)

According to Rogers (2003), innovativeness is a continuous variable and while the adopter groups differ considerably, there are no wide gaps between them. However, as mentioned above, Moore (2014) states that in order to be successful in the market, innovative products must cross the "chasm" between the early and mainstream markets. In addition to that, among every two groups there is a gap which represents that when presenting a product, there should be a separate approach to each group. Consequently, Moore (2014) explains that the adoption curve sets out the path to follow when spreading an innovation. That is, moving from left to right, approaching the innovators first, and as soon as this segment is grown, the next category should be approached (early adopters), and so forth until the end of the curve is reached. During this process, one should analyse how the adoption process went for each previous category in order to improve the approach to each next group.

Each category has its values, different motivations, and the channels from which they receive information about new products do not coincide. The gap between the early adopters and the early majority is the largest among the present groups, and it is so vast that it is called "the chasm" (Moore G. A., 2014). Moore (2014) bases the chasm on four main characteristics of

early adopters that alienate the early majority (see Table 3). Due to these characterisation and perception differences, the early majority does not seek to refer to the early adopters in purchasing decisions, this fact contributes to the emergence of a chasm.

The Early Adopters	The Early Majority
- Lack respect for the value of the experience of their colleague - The first people in their industry segment to see the potential of the new technology and try it	- Deeply value the experience of their colleagues - When buying new products, they want to have a feedback from the companies within the same industry segment
- Take a greater interest in new technologies than in their industry	- Tend to devote their time discussing industry-specific issues
- Fail to acknowledge the importance of existing product infrastructure - Building systems from scratch	- Expect industry standards to have been established
- If the project fails, the early adopters are always a step ahead of the disaster - Follow a fast path that will make them jump up the corporate ladder	- Tend to be committed long term to the company at which they work - Very cautious about grandiose projects because the do not want to take the risks

Table 3: Four main distinguishing characteristics between the early adopters and early majority compiled by the researchers (Moore G. A., 2014)

Moore (2014) suggests several ways to overcome the chasm. One of the ways is *the strategy of securing the beachhead*. In this approach, the company focuses solely on one market segment and fully captures it rather than trying to "kill two birds with one stone". Once the competitors are excluded and the company is dominating the market, it begins to move towards taking over the next segment using the captured segment as the base. The author also emphasizes that during the chasm period it is crucial not to be sales-driven, because the most important thing at this stage is creating a customer base that can then be referred to when reaching new market segments, which in turn can only be obtained if customers have satisfied all their buying objectives. The next method is *the whole product concept*. Its idea is to minimize the gap between the expectations that the customer formed during a marketing campaign and the real properties of the product and the value it delivers. The further to the right we move along the innovation adoption lifecycle, the more important it is for each group that the proposed new product is supported by some additional features, products or services that simplify the implementation of the new product. Thus, the product-planning is necessary, where the company is considering the customer's problems and overall needs, ensuring that the customer receives the whole product. Another way of facilitating the process of crossing the chasm is to find *partners and allies* to accelerate the formation of infrastructure for the product

within the selected segment, through cooperation in delivering the product to the client and in the development of marketing strategy. *The creation of competition* can also serve as a driver for the adoption of a new product by the mainstream market, since for the participants of this part of the market, an important component in the purchasing decision process is a comparison with alternatives offered by competitors. The last two strategies mentioned are *distribution* and *pricing*. When crossing the chasm, it is essential to find the most fitting distribution channel that best suits the chosen target market strategy, and that also depends on the price category of the product. Since the goal of the company crossing the chasm is to become a market leader, the price of a product must communicate that. As well as the selected pricing can make it easier or harder to sell the product.

3.3 Innovation in the Construction Industry

Slaughter (1998) offers a definition of innovation that is commonly used and accepted by multiple researchers and adjusted to the construction industry (Oyedele, Owolabi, Oyedele, & Olawale, 2020) (Yusof, Kamal, Kong-Seng , & Iranmanesh, 2014) (Rigby & Garvin, 2012) (Blayse & Manley, 2004) (Hosseini, Chileshe, Zuo, & Baroudi, 2016):

> *"Innovation is the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change."* (Slaughter, 1998, p. 226)

(Slaughter, 1998) also introduced five models of innovation adjusted to the construction industry. The first two are (1) *incremental* and (2) *radical innovations* which have been discussed in the preceding section 3.1. In addition to those, the author also differentiates between (3) *modular* and (4) *architectural innovation*. It has to do with the effect on other components. Modular innovations do not change other components or systems which is similar to Moore's (2014) continuous innovation. Architectural innovations are the opposite and influence other construction activities. Consequently, the overall change is more significant. Those can be compared with discontinuous innovations which were discussed in 3.1 (Moore G. A., 2014). The last model that the author presents is called (5) *system innovation*. That is about various innovations that are independent of each other but need to form linkages in order to work. Consequently, it can be stated that innovations can make an impact, but on the other side, innovations can also be influenced which will be discussed in the next section.

Blayse & Manley (2004) collected six different key influencing factors on construction innovation: clients and manufacturers, the structure of production, the relationships between individuals and firms within the industry and between the industry and external parties,

procurement systems, regulations/standards and the last one the nature and quality of organizational resources.

1) Clients are the ones who can promote construction innovations. Through their R&D initiatives and their continuous learning cycle, manufacturing companies constitute the main drivers in the industry.
2) Analysing the structure of production, Blayse & Manley (2004) indicate that there is the one-off nature of building projects which can hinder knowledge transfers and lead to the inapplicability of the innovation to other projects. The nature of the product itself also plays a role, because the general expectancy in terms of proof of concept and high durability has to be met. The multiple numbers of actors participating in a project can also represent a hurdle as communication becomes more complex and one project is divided into multiple phases leading to interrupted workflows. A traditional management style with low flexibility constitutes another barrier to innovation.
3) Industry relationships also have an effect on innovation. As just mentioned, the projects are discontinuous and so are often the collaborations between firms. That means that learnings are often lost and not applied in preceding projects. Disseminating the knowledge and transmitting information through "brokers" can counteract.
4) The level of the innovativeness of procurement systems also affects innovation in the industry. A lot of contracts have a rather conservative view with a competitive approach which results in low innovation outcomes. Instead, contracts that encourage team integration and partnering lead to more innovation.
5) Another factor is about the governmental regulations which require knowledge gain and have an effect on technological change. It can force the industry to innovate and increase the demand for new technical innovations.
6) Organizational resources address the culture and the absorptive capacity of firms. Skills, an appropriate attitude, a strategy and processes are needed in order to benefit innovation.

Four more influences in terms of innovation drivers were collected by Bossink (2004): environmental pressure, technological capability, knowledge exchange and boundary spanning. The first one is about demanding markets or policy instruments like regulations. Technological capabilities address the ability of testing and evaluation of new products (also with external collaborations) and technology leadership strategies. Knowledge exchange in terms of R&D departments, networking, sharing innovation information also pushes innovation. The last boundary spanning is about involving clients, integrating diverse disciplines and the specific coordination of innovation processes.

Regarding change and new innovation, the construction sector represents an especially interesting industry. Over decades, multiple researchers addressed that the industry is known for its low innovativeness and its conservatism (Blayse & Manley, 2004) (Xue, Zhang, Yang, & Dai, 2014) (Khatatbeh, 2021). Tangkar & Arditi (2000) argue that the industry innovates slowly which refers to the pace of innovation. In the book "crossing the chasm", Moore (2014, p. 60) states that "[c]onservatives, in essence, are against discontinuous innovations. They believe far more in tradition than in progress. And when they find something that works for them, they like to stick with it".

Hardie (2009) points out that it has to do with the construction industry's attitude towards change and that there are different factors explaining the reasons. The first one is about the fact that multiple small businesses or sole traders participate in the construction; the second one addresses the relationships to the clients in relation to order management. The next factor talks about the presence of discontinuous projects which means constructing a building starts with order and ends when it is fully constructed. The general low R&D intensity represents another aspect and the last point that was mentioned is about the strict regulatory environment. But there are also other points of views that state the opposite. Winch (2003) did a small study and compared the industry with other sectors in terms of innovativeness. He concluded that there is no evidence the construction industry lags behind other industries regarding innovation. But he also mentions that there is a need for a faster rate of innovation and room for improvement.

Lastly, it should be mentioned that there are also negative sides regarding innovation. Seaden, Doutriaux, & Nash (2003) mention that innovation is connected with risk, investments, resistance within companies and change. In contrast, the resulting competitive advantage can be seen as a reason why firms should innovate. It should also be pointed out that innovation is not only beneficial for firms but also advantageous on a regional and national level as it leads to economic growth (Blayse & Manley, 2004).

4. Methodology

In the following sections the research strategy, the research design including the approach and procedure of the study, the applied research methods which consists of primary and secondary data collection, the research analysis, literature review, research quality and finally, the limitations of the study are debated.

4.1 Research Strategy

For this study, the authors decided to do an inductive approach as the authors make empirical observations in order to build a theory. The authors applied a qualitative approach for the data collection by conducting interviews. That approach is suitable for this study because in order to answer the research questions it is crucial to understand the point of view of the respondents, and not limit them with the predetermined answer choices. Thus, the authors were able to come up with new or follow-up questions during the interviews, which bring more insights on the relevant topic and make subsequent interviews more effective (Bell, Bryman, & Harley, 2019). Moreover, a qualitative approach was necessary, as the authors did not have enough knowledge about the topic to prepare narrow questions in advance. When it comes to epistemology, the interpretive approach was followed in this study. It is about understanding human behaviour. That means the focus was on the different perspectives of each participant. Personal views relating to the research topic were gained with the help of interviews (Bell, Bryman, & Harley, 2019).

4.2 Research Design

Research design is about various frameworks that can be followed to first collect and then analyse data. This study can be defined as a single case study (Bell, Bryman, & Harley, 2019), based on the company *House of Hemp* and hempcrete. The case study approach was chosen in order to conduct a comprehensive study, as the identified research questions demand a deep and extensive examination, as well as the focus is mainly on explanatory questions such as “how” which is common for case studies (Yin, 2018). The definition by Yin (2018) of a case study also addresses the scope and features. Case studies are real-world cases and include the in-depth examination of a contemporary phenomenon, a big number of variables and sources of evidence. The phenomenon is represented by the adoption of the construction material hempcrete. The variables are the factors, barriers, drivers, influences etc. and the sources by the high number of interviewees.

Regarding the approach, the research study was initiated by *Peter Holmdahl*, the co-founder and owner of the start-up. In that way, a close collaboration with the co-founder during the research process allowed the authors to obtain the necessary contacts, as well as find quick access to relevant sources for data collection. Figure 6 gives a clearer overview of the design approach.

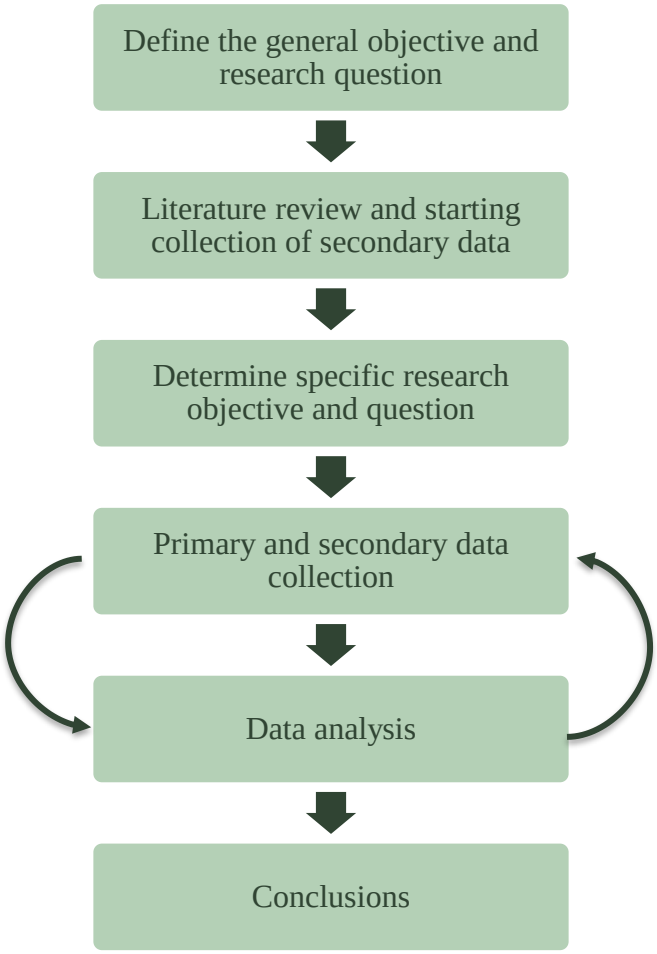

Figure 6: An overview of the research process, compiled by the researchers.

The initial suggestions from *Peter Holmdahl* regarding the research study touched upon the theories of business modelling and innovation diffusion, but no research question was determined initially, and only general ideas were discussed. That meant, topics had to be identified by the authors that needed a closer investigation. The research was done on the following theories: innovation diffusion, the creation of new markets and sustainable business models. As the research questions could not be defined, because more insights were necessary, the authors decided to start with an exploratory approach and conduct a literature review and start collecting secondary data. The purpose was to generate a basis of knowledge about the construction industry, its players, driving forces, dynamics etc. and investigate the material hempcrete more closely. After analysing research papers and studies while examining the

industry, the authors came up with the research questions. According to *Peter Holmdahl*, so far, the company had around 20 customers and the material hempcrete is not known in the market which means the start-up has not reached the mainstream market (later groups of the diffusion process). As the company *House of Hemp* is new to the market, the topic of innovation adoption plays a significant role regarding the future corporate development and therefore constitutes a suitable topic. The subsequent data collection and data analysis were part of an iterative process that finally ended in making conclusions.

4.3 Research Methods

4.3.1 Primary Data Collection

The people that were selected to collect the primary data can be categorized into two groups which makes the collected data more diverse and richer. The first group consists of six people who are experts regarding hempcrete. That means they have either adopted the material or done a lot of research about it and they encourage the usage of hempcrete. That information and contact data were provided by *Peter Holmdahl*.

Regarding the second group, the requirements for being a suitable candidate were stricter. The first two and main criteria made were that the interviewees had to be potential adopters of the material and needed to work in a Swedish company/institution in the field of construction, engineering, architecture, building consultancy, real estate management or building project management in municipalities. Hence, before contacting them, the authors conducted a little research through social networks and online search engines and checked in what position and in what company the person is working in order to make sure that he or she could provide the relevant answers.

The third criterion has to do with the knowledge of sustainability. That was ensured by using a list of contacts from *Peter Holmdahl* which contained a membership status at LFM30 which is "a local initiative in Malmö to create a geographical game plan to accelerate the construction sector's climate change and implementation of Agenda 2030" (LFM30, 2021), where the co-founder of *House of Hemp* is also a member. The authors decided to use the list as the main source for potential interview partners, but if the person was familiar with sustainability, it was also fine.

The final restriction has to do with the fact that the company *House of Hemp* has not reached the mainstream market which means the current and future short-term customers are part of the early groups of the diffusion process (Moore G. A., 2014). For the further development of the company, the adoption process of those groups is relevant to understand. Therefore, the interviewees should belong in those early groups which was ensured with a survey that was

sent to respondents prior to scheduling an interview. Even though the survey was limited with a low number of questions and the results cannot give 100 percent correct conclusions, it gave the authors an impression and it served as a basis for questioning the participants during the interview. Three questions gave conclusions regarding the characteristics and behaviour of the participants which helped to categorize them into the different groups of the diffusion process. Further description and the final results can be found in Appendix B - Survey Questionnaire "Potential Adopters" and Results. A summary of the required criteria for the candidates can be found in Table 4.

	Group 1: Experts	**Group 2: Potential adopters**
Criteria	• Have adopted hempcrete and/or have done in-depth research • Encourage the adoption of hempcrete	• Could adopt hempcrete • Work for a Swedish company in field of construction, engineering, architecture, building consultancy, real estate management or building project management in municipalities • Member of LFM or experience with sustainability • Part of early market (early groups of diffusion process)
Number of interviewees	6	16

Table 4: Overview of interviewee groups

In total, the authors sent emails to 132 people. The snowballing effect could be detected twice as two potential candidates forwarded the email to colleagues who were a better fit and willing to take part in the research study. The authors received a total number of 28 positive responses, from which 23 people were interviewed. One interviewee from Group 2 turned out to be unsuitable as the person works for a company that develops eco-friendly materials themselves and therefore cannot be an adopter. In the end, the 22 people who work at 12 different companies, two municipalities and one university participated and contributed to the study. The interviews #1-6 which are displayed in Table 5 were held with the experts; the rest are potential adopters. Referring to section 2.2, the authors were able to collect data from a diverse group of people including a minimum of one respondent from each type of adopter which also explains the size of the sample. Their profiles in addition to the experts are discussed in Table 5 below.

Inter-view	Company	Person	Description
#1	University	Interviewee U	Scientific researcher, teaching at the university, has done research on hempcrete at a Swedish university for 10 years, and worked as a building engineer.
#2	Municipality	Interviewee M1	An innovation manager at a municipality working on a project to construct a fossil free building.
#3	Municipality	Interviewee M2	Urban planning strategist who came on a two-day trip to Paris to see Hempcrete construction and renovation.
#4	Construction consulting company	Interviewee CO1	An architect who is building a small house (32m2) in his garden made out of hempcrete.
#5	Architecture company	Interviewee A1	An architect who wrote his final paper on hempcrete performed at a Swedish University. Has been drawing and building hempcrete houses in Sweden in the past two years.
#6	Supplier	Interviewee S	*Peter Holmdahl* is the owner of *House of Hemp*.
#7	Construction company	Interviewee C1	Environmental and sustainability specialist
#8	Construction company	Interviewee C2	Project manager and business developer
#9	Construction company	Interviewee C3	Site manager
#10	Engineering company	Interviewee E1	Principal structural engineer
#11	Landscape architecture company	Interviewee A2	Intern with high interest in sustainability topics
#12	Architecture company	Interviewee A3	Architect and environmental coordinator
#13	Landscape architecture company and consultancy	Interviewee A4	Landscape architect, responsible for the sustainability management and development of the firm

#14	Municipality	Interviewee M3	Project manager
#15	Architecture company	Interviewee A5	Architect with ten years of experience
#16	County council	Interviewee CC	Environmental coordinator
#17	Real estate company	Interviewee R1	Environmental economist and specialist in the environmental certification of buildings
#18	Consulting company	Interviewee CO2	Environmental consultant
#19	Municipality	Interviewee M4	Project leader for a sustainable construction project
#20	Municipality	Interviewee M5	Project manager and former architect
#21	Architecture company	Interviewee A6	Sustainability manager
#22	Real estate company	Interviewee R2	Project manager

Table 5: The list of people interviewed

All of the candidates were contacted via e-mail, and it was stated that *Peter Holmdahl* forwarded the contact details which in the opinion of the authors increased the likelihood of their willingness to help. It was also indicated in the message that the purpose of the interview was for a master's thesis research, which, according to the authors, could increase the likelihood of receiving a response. In addition to the interview request, the potential adopters were also provided with the link to the *Google form* survey which is available in Appendix B - Survey Questionnaire "Potential Adopters". By taking part in the survey, the respondents automatically confirmed their participation in the interview. The purpose of choosing a small survey in addition to the interviews instead of including the questions in the interview was the types of questions that were asked. E.g. a scenario with various options of choice was given and a scale was included which are easier to answer when reading them. Additionally, if resulting from the answer choices it could be concluded that the potential candidate had a rather conservative point of view and belonged in the latter groups of the diffusion process, the person could be sorted out before an interview was held which led to an efficient process. The questions in the survey did not require comprehensive responses and the limited answers options were sufficient, which also allowed the authors to save time.

After receiving a positive response, the authors scheduled a meeting and conducted interviews through online video calls via software such as *Zoom* and *Microsoft Teams*. This was a forced

measure and physical meetings with the interviewees were not possible, due to the fact that at the time of the interviews the authors were located in different countries, and also the epidemiological situation in Sweden did not allow for face-to-face meetings. The interviews took place between calendar week 9 and 16 and lasted an average of 42 minutes. Interviews and discussions with the co-founder *Peter Holmdahl*, where information and data could be gained, were held throughout the whole process of the study. In order to allow the authors to conduct a high-quality analysis of the data obtained, each interview was recorded on a voice recorder or through the built-in tool of the software used. Before the interview, all respondents were asked if they did not mind that the interview is being recorded. The authors do not have a sufficient level of Swedish to conduct interviews. Therefore, the authors communicated with the respondents in English. In order to allow the respondent to focus on one person, the researchers took turns leading the interviews.

The questionnaires for the two groups were designed differently. For the experts, the authors wanted to know more about their experience regarding hempcrete and the industry (Appendix A - Interview Questionnaire “Experts”). The questions were directly targeted at their projects, but also at their experience with the whole industry. Looking at the second group, the potential adopters, the list of questions was longer because the focus was to find out more about their individual adoption process of new materials within the company (Appendix C - Interview Questionnaire “Potential Adopters”). The different stages by Rogers (2003) helped to formulate the questions. Both questionnaires were semi-structured as the approach was exploratory. That enabled the authors to have guidance throughout the interview, but it was also essential to broach the interesting subjects again and ask follow-up questions. In that way, the interviewee could express himself/herself freely and the interviewers had the chance to react adequately to the responses which was essential due to their individual backgrounds, job positions and projects. Consequently, directions could be taken that cannot be planned in the first place leading to new and unforeseen insights.

4.3.2 Secondary Data Collection

For the secondary data, the authors used a variety of digital and reliable sources such as *Statista*, official Swedish databases, reports from the *U.N.* or *E.U.* and others, to find relevant information. The researchers tried different keywords to find the needed data (e.g. construction industry, hempcrete, industry volume, environment etc.). Secondary data was collected at all stages of the study before conclusions were drawn. The purpose of collecting this data was both to give researchers a deeper understanding of the topic, and to help find data that can contribute to the study. As a result, during the research, the authors found and used various newspaper articles, reports, journals, statistics and diverse web sources. The authors even attended the online conference *Industrial Hemp - Innovation for a Biobased & Fossil Free Future* where

people from all over the world shared their knowledge which provided the researchers with valuable insights.

4.4 Data Analysis

After several applications were being tested by the two authors, they decided to work with *ATLAS.ti* which is a well-known software for qualitative data analysis. In addition to that, it facilitated online group collaboration. The services of *Office 365* and *Otter.ai* were selected to transcribe audio files of all the conducted interviews to text. As a lot of abbreviations, Swedish words, titles etc. were named that the tool did not capture correctly and parts of the audio files were of poor quality, a lot of text corrections had to be made to make sure the text was correct and ready to be analysed. The process of the data analysis of the study cannot be seen as the final step of the whole research study, but rather as a recurring element in an iterative process. Every week the interviews were analysed before the next interviews took place. That enabled the authors not only to work with the results with the interview still fresh in mind, but also to adjust and improve interview questions for future interviewees.

Survey

The survey that was conducted can be seen as a pre-assessment of the interviewee. It helped the authors to understand the attitude of each candidate towards innovation. The answer choices were designed according to the characteristics of the five groups in the diffusion process. When looking at the answers of each candidate, it could be investigated whether the participant belonged to the early or the last groups of the diffusion phases. In addition, the researchers went through the responses and investigated if all of the selected answer options fit together. If anomalies could be found, they were addressed during the interview. One question that addressed the risk attitude was further investigated during the interviews to gain more insights regarding the reasoning behind it. To summarize the findings, with the help of the software *SPSS* and *Excel* descriptive analyses like charts were used to visualize the results.

Interviews

Regarding the analysis of the interviews, a thematic approach was chosen (Bell, Bryman, & Harley, 2019). The first step was to transcribe the interview audio. After that was done, the authors carefully went through the transcriptions and created and assigned 1st order codes. Then, these codes were merged if a connection or relation could be determined. Subsequently, the 2nd order codes were assigned to the themes positive and barriers. Afterwards, the authors realised that the barriers could be divided into dependent and independent influences which resulted in assigning the 2nd order codes of barriers again, this time categorized according to their dependence. Afterwards, the codes that showed a high number of repetitions were chosen

to be further investigated and interpreted by comparing the coded interview responses. All the codes that contributed to the study and helped to answer the research question can be seen in Table 6. Codes that were ultimately not merged into 2nd order codes and did not show any significance are not displayed in this table.

1st order codes	2nd order codes	Themes
Open-minded, curious, explorative	Personality	Positive influences
Municipalities, (big) companies, pioneer, architectures	Forerunners	
Sustainability movement, sustainable innovations, awareness, sustainability development, need, green materials, climate impact, progress, change	Sustainability awareness	
Demand, pressure from clients	Increasing demand	
Profit, competitive advantage, pressure from competitors, image, reputation, priorities	Corporate goals	
Sustainability department, sustainable strategy, sustainability consultant, sustainability guidelines, sustainability investigation	Sustainability environment	
Test beds, test sites, testing, test facilities, certifications, databases, proof of concept	Assessment	
Forces from government, pressure from government, setting maximum level, ease regulations, more regulations, obligations	Governmental regulations and building requirements	
Paris agreement, government's demand, governmental projects	Governmental agenda	
LFM30, sustainability projects, sustainability programs	Initiatives	
Climate, cold weather, coldness, climate affecting materials, country-specific conditions	Climate conditions in Sweden	Negative influences
Big companies, dominating the market, setting standards	Industry dominated by large companies	
Problem in the 80s, disaster, bad experience	Negative experience	
A lot of players	Nature of the industry	
Lack of awareness regarding sustainability, timing	Timing	

Tenders, problem with tenders, competition for tenders	No competition for tenders	
Business/ money driven, time pressure, subordinate role, risk averse, sticking to old habits, no change	Risk aversion, old habits, priorities	
Potential damage, failure, uncertainty	Risks	
Too much work, no time, no room for extra work	Lack of time	
Responsibility, in charge	Decision-making power	
Misconceptions, misjudgement, bio-based materials, cost	Material characteristics	
Restricting regulations, no freedom due to regulations	Regulations and building requirements	
Source of information missing	Lack of information	
Way of calculating and assessing, excluding important factors	Limited view	
Sceptical view, missing trust	Scepticism	

Table 6: Codes and themes used for the analysis

4.5 Literature Review

The primary sources that were used to gather relevant and scientific papers were the library search engine from the *University of Gothenburg* and *google.scholar*. The following keywords were used for the first research in multiple different combinations: construction industry, building industry, construction material industry, innovation, innovation diffusion, innovation adoption, green/eco/environmental construction material and sustainable business model. In addition to that, the authors scanned the references of papers that were identified to be valuable in order to find more suitable sources. The goal was to use only papers of high quality which could be ensured by looking at the journal that published the paper or at the number of citations. Another aim was to use contemporary papers meaning they have been published in the last couple of years. In case those could not be found, older sources had to be referred to.

4.6 Research Quality

When conducting a research study, certain criteria should be used to evaluate qualitative research and to assess the quality of the study. As the relevance of validity, reliability and

objectivity for qualitative studies are often questioned by researchers, alternative criteria which are more suitable for the nature of qualitative research will be examined. It addresses credibility, dependability and confirmability (Bell, Bryman, & Harley, 2019).

Credibility similar to validity is about working with the principles of good practice which can be confirmed when looking at the alignment of the methodology. One strategy that can be followed addresses triangulation in relation to data, researchers and methods. Data triangulation means making use of multiple sources referring to interviewees. That means the authors decided to conduct interviews with not only potential adopters, but also with people who have expertise in the relevant field. That adds diversity to the results and increases credibility. Triangulation regarding researchers addresses the fact that not one, but two researchers worked on the study prevents biases and increases credibility. The multiple methods used including primary data collection with interviews and surveys and the secondary data collection with reports and statistics also contribute to credibility. Another point that strengthens credibility has to do with the level of engagement of the two authors which was long-lasting. A lot of time was invested in order to learn more about the context and gain the relevant knowledge to be able to conduct the study (Bell, Bryman, & Harley, 2019) (Korstjens & Moser, 2017).

Another criterion is called dependability which has some parallels with reliability. It is about the researchers' interpretations and evaluation deriving from the collected data. To enhance dependability, the authors kept and saved all records including audios, transcripts, *ATLAS.TI* files, notes and more during the whole process of the study. Additionally, the researchers kept the study as transparent as possible by providing a precise description of the findings and analysis and a high number of quotes as evidence to comprehend how the conclusion could be reached (Bell, Bryman, & Harley, 2019) (Korstjens & Moser, 2017).

The last criterion confirmability refers to objectivity and the extent to which the study can be confirmed by other researchers. Qualitative research has often been criticized for being too subjective which highlights that objectivity should be one of the main goals. That was followed by the authors as much as possible by suppressing personal values and trying to look through the eyes of the interviewees. The authors also tried to show clear links between the findings, analysis and interpretation and give a detailed specification of the approach and procedure (Korstjens & Moser, 2017).

4.7 Limitations of the Study

Every research study, such as this one, is restricted by nature. The most obvious one of this study is the time that was set by the university and could not be influenced by the authors. The

authors had to ensure that the study could be completed within the specified time frame, which could not be extended even if it was required during the study. The lack of knowledge of the Swedish language constitutes another barrier. When researching Swedish regulations, companies or other relevant topics, knowing the Swedish language would have been a decisive benefit. With the use of translation services, that barrier was reduced as much as possible. Additionally, the fact that the conducted interviews were held in English can also negatively affect the respondents' ability to fully express their thoughts, since for the majority of the respondents Swedish is their mother tongue. However, the authors believe that this did not significantly influence the result or the quality of the collected data. Another limitation is the fact that due to the global pandemic the authors were not able to meet in person. That means discussions and analyses had to be done online, through video calls via Zoom, or through text messaging via other online tools. The bad quality of sound and video that occasionally occurred and the absence of tools like whiteboards complicated the cooperation.

5. Findings

This chapter consists of three main sections which are structured as follows. The first one is about the general findings of the research study. Subsequently, the following two chapters are divided into positive and negative influences. The authors chose to use quotes from the interviewees in order to support the findings, part of the quotes that are not specified in the text can be seen in Appendix D - Additional Quotes, to get a more in-depth and detailed overview.

5.1 General Findings

Interviewee C1, C2, A4, CO1 confirm that the speed of innovations in the market is going too slow. That is due to the fact that there is a lot of capital involved and the processes are very long (*Interviewee C2*). When it comes to climate change and the signed Paris Agreement, the industry needs to speed up (*Interviewee A4*) and adopt new innovations quicker. Otherwise, the goal to reduce CO2 emissions cannot be achieved. There was one participant who stated that the number of new innovations is high, but they do not get adopted:

> *"I think there is a lot of new innovations, but it's difficult for them to make the market. They are there, but they cannot really squeeze themselves in." - Interviewee M5*

5.2 Positive Influences on Innovation Adoption

To understand the innovation adoption process, the positive influences on the process should be observed and investigated. The respondents pointed out various drivers, conditions, people etc. that can accelerate the adoption of innovations in the construction industry which will be discussed in the following.

Adopting a new innovation has a lot to do with personality. It is about what kind of person can drive the sustainability movement and encourage new innovations. *Interviewee R2* thinks that it is about people that are truly interested in the topic. The ones that understand that it is the future and there is no way around it are the key players. Companies that are of a different opinion will not survive according to *Interviewee R2*. The same was detected with *Interviewee R2* who has also never heard of it before but seemed very interested and open and asked a couple of questions wanting to know more about the material. That positive influence can also be confirmed by looking at *Interviewee CO1*. The respondent who has adopted the material is a very open-minded and curious person who is not afraid to try new things:

"And I've always been open to see what's behind the doors. So therefore, I'm open for new materials and look into all these kinds of new ideas." - *Interviewee CO1*

The personality is also connected with the importance of certain factors. *Interviewee CO1* mentioned that money, hence the costs are prioritised in the industry. But that mindset has to change in order to fully appreciate the innovation, which is the responsibility of the buyer, because those are the ones who pay and make the decisions. That suggestion was formulated by the architect referring to the clients' first questions about a new innovation:

"I think you need to change the mindset of people. So they can turn the way around. So, the first question should be, 'is it good?'." - *Interviewee CO1*

Another essential factor is the request for proof of concept. People want to see a real building where the innovation was implemented. Otherwise, they are sceptical about the new innovation. *Interviewee U* said there are very few projects with hempcrete in Sweden, however even they can make a big contribution because it can show other people that it is possible to build with this material. *Interviewee S* declared that it is extremely important to show in real time statistically how the material works in the form of test sites.

When new innovations enter the market, there are always people who try them out first. In this case, there are three types: (1) big companies, (2) municipalities that both directly influence the whole market and (3) individuals that make a smaller impact.

Big companies set the standards in the industry which other, smaller companies follow. Consequently, if the large firms innovate and adopt new innovations, the rest follows. For instance, fossil-free steel is being implemented by the big construction companies which means if it will be successful, other companies will follow (*Interviewee C1*). Another driver can be municipalities that take the role of leaders. These can set an example for other businesses (*Interviewee A2, M1, M2* and *S*). *Interviewee A1* considers that the municipalities should be the ones to implement innovations, because it has tools to influence people's behaviour, as well as successful examples of the use of innovations by the government can serve as a driver. On the other side, individuals in the market can also be in the lead. *Interviewee CO1* believes that hempcrete has a lot of potential in Sweden and has a very practical approach by saying that "*if no one else is building it, then I have to build it".* People like *Interviewee CO1* are forerunners who are not afraid to try out new things. They are necessary for new innovations, as they can show other people how the material works. Four interviewees declared that they are the drivers themselves. Architects are idealistic and have the motivation to create good projects for their

clients (*Interviewee A4*), real estate companies also have a big responsibility to demand and contribute to change (*Interviewee R1*), *Interviewee A1* also mentioned that people themselves can contribute to the adoption and lastly, municipalities see the importance of their decisions regarding the purchase of products and materials (*Interviewee M3*) and their role:

> *"I would say that if the driver is from the ones ordering the houses. [...] So it's actually that's why we have tried to as a municipality go forward and ask for: we want something with low climate impacts, and we are ready to pay for that and initiate the drive for change." - Interviewee M4*

It has to be stated that people cannot only get inspired by other people who are the first. It can also come from a movement in general. The construction industry is currently experiencing various difficulties associated with a significant negative impact on climate, and it became a heavily debated topic. A lot of the interviewees (*Interviewee A2, C2, C3, R2*) talked about a sustainability movement happening in Sweden in the last couple of years or even months, where customers and players are more interested in the topic and companies establish the goal to build more sustainably. *Interviewee A4* sees a chance regarding climate awareness development. People are more open-minded towards new technologies and more willing to try new things. Those are more likely to be accepted if they are better for the climate. Four interviewees (*Interviewee C1, CO1, A4, A6*) stated that at the moment climate change is the main focus and people are becoming more aware of it. That awareness can also result in pressure that forces companies to take actions and becomes more and more relevant as the demand rises (*Interviewee R3*) which will be further explained in the next section.

Customer demand also plays a decisive role in driving companies to implement innovations. *Interviewee R2* addressed that for some firms it is necessary to offer sustainable solutions as is requested by the customer. As more and more attention is paid to sustainability, companies have to react and find innovative green solutions in order to be able to deliver what the customer demands. Consequently, the increased market concern regarding climate issues creates the most favourable conditions for hempcrete to enter the market, because the demand for its properties is high. Other drivers are about business development and profit. Those can be done on a voluntary basis depending on the ambition and determination of the company. For instance, one goal has to do with reputation. *Interviewee U* points out that when it comes to sustainability the image of the company can be a driver which means some companies only follow climate actions because of their reputation. Another reason is about keeping up with competitors (*Interviewee CC* and *Interviewee M2).* Implementing innovations can also mean gaining a competitive advantage. Costs, quality and time were mentioned by *Interviewee E1*. Increasing the quality and profit, reducing time and costs can result in competitive advantage

and more corporate success. Gaining advantage through being the best on the market by implementing new innovations was also addressed by *Interviewee C2*. Regardless of the type of motivation, if a company has any goals related to changing and reducing the negatively influencing footprints from construction processes, it becomes a driver for green innovations.

Implementing new innovations is also about the right environment that has to be provided within the companies. A lot of companies are active in that regard. The company, where *Interviewee A4* works, even has a sustainability department consisting of a small group of people. That gives them the chance to set guidelines to work with the projects sustainably. *Interviewee C2* also mentioned that a sustainability department exists in the company, *Interviewee A2* explained that they work with a green index where, after each construction project, different measures like the climate impact or energy performance are investigated. The construction company where *Interviewee C1* is working has a sustainability council that every project has to pass. Nevertheless, implementing sustainability into a company is not as easy as it seems as there are some things that have to be considered. It is essential not only to see sustainability as a separate strategy to the business development strategy. Instead, a sustainable business development strategy should be introduced. The more precise explanation of the integration of sustainability within a business was examined by *Interviewee A6*. If sustainability is not integrated in the correct way, it can turn out into greenwashing:

> *"[...] not having sustainability strategy on one side and business development strategy on the other side, but actually connecting them and doing it in the same development, so to speak, so sustainable business development not having sustainability strategy and business development strategy. But connecting those two. [...] its greenwash if you start by looking at „Where is the business?" How can we put some green paint on it and then sell it for sustainable development? Then it's greenwash, so you always have to identify where you as a business can have the most impact."* - *Interviewee A6*

Another point is about testing which can be done by the companies to assess the new innovation precisely. *Interviewee A4* is someone who wants to try out the innovations in order to evaluate them more precisely, hence to get a proof of concept. Otherwise, the promised material features might not be trusted. That can be done through test facilities as *Interviewee C2* explains:

> *"I guess the interesting thing with [*company*] is that this kind of creates this controlled environment, so when we actually test something, it is possible to evaluate the impact of that change because we can relate to other projects which would*

> *otherwise have been made in the traditional [*company*] way, so I guess as a trial ground and test facility, it's very interesting for us to try new things."- Interviewee C2*

The company where *Interviewee C1* works does not want to take the risk by implementing the material for actual projects right away, but rather do small tests beforehand. There are also other approaches that companies follow. Some hire consultants to do the testing (*Interviewee C3*), one company does the implementation on a small scale (*Interviewee R1*) by using the innovation for only one building which is their way of testing or by implementing only one new material instead of multiple ones in one project (*Interviewee M5*) and another firm has its own testing lab or trial ground (*Interviewee C2*).

A different way of assessing the material is getting it certified or evaluated and then put in a database. Some interviewees specified that they only consider implementing materials that are certified with a specific certification or are listed in databases. *Interviewee E1, M3* and *R1* stated that the material should be approved by the regulatory authorities or have certifications. *Interviewee M2* indicated that it is important for hempcrete to get a relevant certification to have a demand. Seven interviewees stated that they usually look at the type of certification the material has or the database in which the material is mentioned. The specific examples that were named by the respondents are *BREEAM-SE, NollCO2, Miljöbyggnad, City Lab, LEED, CEEQUAL, GreenBuilding, Environmental Product Declaration (EPD), Swan Ecolabel, EU Ecolabel, BASTA and SundaHus.*

> *"They indicate that you do not have any like phase out chemicals in it [...] And they also put in criterias for different materials [...] That is a way to evaluate materials, if it is like red in these lists, you should not use it." - Interviewee A2*

> *"Third party organisations that look at materials and put their stamp on it saying this is good in relation to these sustainability aspects and so on. And then we can use their database to pick materials that are more or less sustainable." - Interviewee A6*

When it comes to the evaluation process, adopters need all sorts of information in order to assess the material. *Interviewee A6* requests a more holistic overview including all the factors concerning sustainability as "*it's very easy to talk about the good parts of sustainability, but not the negative parts".* According to the interviewee, the negative impact and also different angles including the wood industry, land use and biodiversity have to be observed in order to be able to assess the innovation more precisely. That requires a detailed information catalogue of the material. Another important stage where knowledge transfer is relevant is when it comes

to the actual implementation. As *Interviewee E1* pointed out, it does not have to be a program that does all the calculations, but a pdf file is necessary in order to work with the material in an efficient way.

> *"And you need to provide information in a very easy to use manner, and it doesn't have to be automated calculations or anything like that. It can be PDF document sheets. But it needs to be provided."* - *Interviewee E1*

Another positive influence identified by the authors is government regulations. The Swedish government has the authority to introduce new regulations and laws in relation to the construction industry. The introduction of new regulations means that the requirements in relation to construction processes are changing, accordingly, it is highly likely that participants of the industry will need to change their approach to some procedures and construction routines if their current approach does not comply with the new regulations. Thus, companies and other actors will start looking for new solutions, which fosters the enabling environment for adopting a new innovation. *Interviewee M1* gave an example about setting a maximum level *"and then the companies can use their expertise to solve that and then we will have many different solutions and learn from that."* Another example was provided by *Interviewee A6*. If suppliers are not evaluated, as *Interviewee A6* suggested, they perform on their current level and do not see the urge to innovate. Those mandatory evaluation processes could be introduced by the government. *Interviewee A1* had a similar idea by suggesting making environmental declarations an obligation for every company. Governmental decisions in terms of new regulations mean companies do not choose to innovate but are rather forced (*Interviewee CC*). That puts pressure on the firms to innovate or adopt. An interesting observation is that the opinions of *Interviewee M2* and *Interviewee A1* differed, as the first pointed out that in order for companies to adopt new innovations, the government should ease regulations and give construction more freedom, while the second pointed out that, on the contrary, new regulations could force companies to take new actions that can subsequently have a positive impact on the diffusion of innovations. One interviewee had a concrete suggestion of what should be done in order to solve that problem:

> *"I think it would be an even bigger driver if you were allowed to, let's say, do things quicker and do things, maybe perhaps a combination of more regulation in certain areas and less regulation in other areas would be the best recipe for a more innovative industry. Because that would allow you to take more chances, let's say or take more projects would be able to be implemented with less risk if you could be certain that you were allowed to implement them."* - *Interviewee C2*

Governmental agenda can also have to do with setting various goals, including those related to climate impact, environmental issues and sustainability in general. One conspicuity that was discovered during the interviews has to do with the fact that most of the interviewees mentioned the *Paris Agreement* from the *U.N.* which is also part of the Swedish agenda from the government. That program includes a goal of CO1 reduction which also affects the construction industry. A lot of the interviewees see it as their responsibility to contribute in order to achieve that goal in the scheduled time frame. That means green solutions are increasingly sought after. Four respondents mentioned that the government, in general, can help the innovations to be adopted by initiating new projects and setting new goals with a specific focus (e.g. to reduce carbon footprint).

5.3 Negative Influences on Innovation Adoption

Various factors and circumstances can serve as a negative influence that affects the decision of a potential user to adopt an innovation, and therefore hinders the diffusion of innovation. The respondents expressed their views on these influences and elaborated on what, in their view, are negative aspects that affect the introduction of innovation and the subsequent process of its adoption.

The construction industry is known for being money and business-driven. That is also reflected in the prioritisation of the buyers. Eight respondents (*Interviewee M2, C1, C3, E1, M3, A4, CC* and *CO1)* pointed out the importance of low costs. *Interviewee R1* considered working with hempcrete in one of their projects, but also remembered a disadvantage meaning the price. The interviewee recalls the material being quite expensive compared to other solutions such as concrete. As well as if a new material costs more than the one currently in use, then this may be an obstacle to its application. *Interviewee CO1* also pointed out that innovations can be spread fast if they are cheap.

> *"It is always a money question. I would buy a slightly more expensive project if it is better, but it cannot be that much more expensive, we do not have that kind of budgets and projects, unfortunately." – Interviewee C3*

> *"The cost is very interesting and not for me, but for the ones who are paying for the materials, and it is usually not me. But I do not want to suggest something that is overly expensive and not have a reason to be that." - Interviewee CO1*

Interviewee A2 and *C1* also highlighted the cost of the material as a potential negative factor, however, these respondents identified this as a problem because people may give special emphasis to the price, neglecting other benefits the material may have. Likewise, *Interviewee A4* stated that some companies have a more holistic approach and they consider not only the costs of the material at the initial stage, but also how the material will affect the overall cost of the project in the long term. However, there are still companies that will look at the costs only at the beginning of the project, and that could have a negative effect on the adoption process. *Interviewee A4* talked about the benefits of a more holistic approach:

> *"Some companies are more holistic and could be interested in a process that maybe costs more in the beginning, but it cuts the building time in half and then they can make money by not having to pay as much interest on their loans for building the building. And even if the framework of the building itself is more expensive, they can sell the apartment earlier and that reduces their risk. And others think the other way around [...]."* - *Interviewee A4*

One other important aspect is the overall view of a project when it comes to energy assessment. Regarding energy consumption, *Interviewee A2* said that the focus was only on the energy savings, whereas now, the emissions that emerge from the production of building materials are also being considered. That shows that the view is changing from a rather narrow to a more holistic approach. *Interviewee U* says that compared to 10 years ago, only the energy performance (u-value) of the user phase (of the building) was important, whereas today, the energy performance of the whole process is at the centre of attention which also includes the materials. *Interviewee A1* adds that now not only the energy performance which has always been standard measurement is important, but also the lifespan of buildings. *Interviewee CO1* adds that the focus should lie on the long-term assessment and not just on the finished product.

Old habits are another factor that diminishes the chances of innovation being adopted and triggers scepticism among the potential adopters. *Interviewee A2* stated that there are so many products that are used just because they have always been used, and people do not think "outside the box" and the hardest part is to get people to use something new. *Interviewee M3* and *Interviewee A4* provided a similar view, adding that clients are afraid to try something new and they think it is safer to stick to the previous methods. Equally, *Interviewee CO1* emphasized that people do not know what the new products are and they want to have confirmation that it is as good as the ones they used before. The same respondent added that another negative factor is that certain companies build huge buildings with a large number of apartments, and therefore the consequences of failure are much higher. As well as small companies may not have many resources and funds to make innovative choices, because it might be too risky for them.

Speaking of the risks, seven respondents (*Interviewee C1, C2, C3, R1, CO1, M4* and *M5*) brought up that in general if they see a risk in an innovation this may be a reason not to consider its implementation. Some interviewees (*Interviewee C1, C2, CO1, M4, M5* and *A6*) have linked these risks to specific consequences, such as the problems with the indoor environment (*Interviewee A6*), troubles with the maintenance of the building *(Interviewee M4)*, durability and appearance after some time (*Interviewee A2, A4*) which is also pointed out by *Interviewee CO1* who said that they would assess how the material looks after several years. There is also the risk of losing market position (*Interviewee C2)*, the risk that if the material is implemented all over the building and if problems appear, then they are also present all over the building (*Interviewee C1*). Another risk has to do with the fact that if a company builds huge buildings with a large number of apartments, the consequences of failure are much higher (*Interviewee CO1*) and the last, which is detailed in the quote below.

> *"[...] when I put something out there it costs a lot of money and I need to make sure that it actually can work for that time. If you take a floor material for school, for classroom and that does not work [...] maybe I can find the money to just change the floor, but can I find the money to close down the school [...] And these consequences can be very big. So if I am going to try something on a bigger scale [...] I need to decide how big are the consequences, how big are the risks? It is nice when it gets better and innovative, but I need to measure it to the risk."* - *Interviewee M5*

Interviewee E1 believes that the fact that the supplier of the innovation is usually a small company or that there is only one or two companies on the market providing it can have a negative effect on the decision to adopt the innovation. Because there may be problems with the required amount of supply, and the company providing innovation may not be able to deliver the required amount of material on time. *Interviewee C1, Interviewee C3* and *Interviewee A2* discussed the importance of ensuring that the proposed innovation can be delivered by the supplier in the required quantities and on time. *Interviewee M4* experienced a case where the supplier could not deliver due to Covid-19, so alternative solutions had to be chosen. Likewise, if the potential adopter of the innovation is a governmental customer, they may not be allowed to use the material that only one company on the market provides, because there would be no competition for tenders:

> *"There was only one company producing it in Sweden, so we did not have the right to set a requirement on that in the contract because it would be a breach against the law [...] we do not have the right as administration to specify something that only*

one person produces. It would be a problem for the competition. [...] You almost have to name this company. You have to describe it very specifically, but if there are more than that, it is easier." - *Interviewee M3*

Another problem for governmental clients such as municipalities is that the person that is willing to adopt a new material might not have decision-making power. *Interviewee M5* discusses that if you come up with a really good innovative material, there are so many levels you need to convince to implement it, such as architects, project managers, facility managers and finally construction company. There are some key persons in this process, but in general a huge amount of people produces hundreds of decisions to build one house. *Interviewee M3* expressed the following view:

"If you are working at a small commune [...] you have these tiny things to do and then there is another person and then there are a lot of laws everywhere so I do not think I have the power as a person to decide which material. So I have to be a little bit risk averse because I know that usually when you propose a new thing, it is really hard and you have to fight to implement it and it takes time [...]"

The regulations and other building requirements set by the government are another barrier that was mentioned by the respondents. *Interviewee C3* said that there are so many requirements they have to fulfil before they can start using a new product. Similarly, *Interviewee R2* stated that the Swedish regulations are very high and companies are building houses that are too good and it takes a lot of materials and techniques that they do not even need, it is too much of everything, and the regulations should be weakened to make sure the innovations get space. *Interviewee M3* also noted that sometimes the requirements and conditions imposed by politicians can limit the ability to try something new due to time pressure:

"If all your politics say that you have to deliver in one year and buy in one year and build in one year because we need a lot of dwellings for example, and it is really hard to say no. Of course we need a lot of dwellings [...] it is a good agenda, but sometimes it can just crush sustainability and if we cannot have this dialogue about what is the priority, it can be really hard."

Interviewee A4 indicated that the barrier for innovation could be the way of how the whole building industry is organised and who is responsible for what and who is paying for what, as well as the subordinate role of architects in Sweden. This respondent elaborated by saying that in a lot of other countries the architects are a stronger group in the construction industry where

what they say means more than what they say in Sweden means. They do not have enough power to force the ability to build a new unit in a specific way. The same interviewee added that how the contracts are usually written is another barrier, because the client normally orders a building and the construction company builds it, but according to the contract, the construction company has quite a lot of freedom in terms of how they do the building, while the end client normally is the one with the sustainability goals. And if the construction industry were organised like it is for example in Denmark, Great Britain, Switzerland or Germany, then the end client would have much more influence on how companies are building.

The nature of the industry is also evident in the fact that it is dominated by large companies. Several of the largest construction companies are leading the Swedish construction market, making it difficult to make changes in the industry, including the implementation of innovations. This has been backed up by arguments such as that these companies have their own concrete factories, and it is unprofitable for them to replace this material with another (*Interviewee C3*). Another stated argument was that these companies are so big and only a few people work with the questions such as sustainability and change in the company. And these people are trying to reach out to thousands of people, it is big machinery (*Interviewee CC*).

Another barrier can be seen in the characteristics of the materials. *Interviewee U* sees a barrier for hempcrete as bio-based materials in general, because they are known for their difficulties with moisture. That prejudice might increase the risk aversion towards green materials.

> *"People are afraid of moisture, fungus and related problems. So, in that way, then hemp and lime, they're afraid of that as well, because it's an organic material."*

Interviewee U also believes that in the case of hempcrete, it has a worse energy performance compared to the alternatives, it works differently from how the industry is building today, and in general people are afraid to build with organic materials due to problems with moisture, fungus and related issues. *Interviewee A1* also added that sometimes hempcrete may have rather negative associations and stereotypes related to cannabis plants that are known for other properties, and that in Sweden there is no single official and comprehensive source where you can read all the necessary information and building guidelines regarding hempcrete and in order to find it you have to search for it and collect information from different sources. Same as *Interviewee A4* pointed out that information regarding the material has to be available, otherwise it makes it more complicated for the potential adopter to work with it.

Furthermore, *Interviewee M1, M2, A5* and *A6* stated that for new material to enter the market another obstacle may be the requirements for certain regulations and necessary certifications,

which can result that the material either cannot be used, or nobody wants to buy it due to the lack of particular accreditations. *Interviewee A4* also highlighted that they have to improve their evaluation process and investigate and work more with various certifications. But at the same time, the material suppliers also need to be better at providing information about their product. Similarly, *Interviewee A5* stated that they expect the suppliers to provide a proper assessment of their products if they are not listed in any database:

> *"Then we normally try to get the manufacturers to get innovative evaluation. It usually costs money, but if someone wants to sell like 10,000 square metres of floor, then they need to have done the proper tests so it can be evaluated."*

The requirement of a material to be tested was also mentioned by other respondents. In order for a company to be able to implement a new material, it must have already been successfully tested by other companies, preferably those based in Sweden. This was mentioned by *Interviewee C1, C2, Interviewee A2* and *Interviewee A2.*

> *"All clients demand that, so we do not have any possibility there we have to use what is tested in Sweden. [...] It is really, really important, otherwise we have fines, you have to pay money back to the client and everything." - Interviewee C3*

> *"[...] it has to be tested in some way before it can be applied in a public environment I think, so it has to be confirmed in some way, anyway. And especially when you are working with public municipalities and such like taxpayer money, I think you must be able to evaluate it." - Interviewee A2*

Some more material characteristics can be a negative influence. *Interviewee A2* said that in general if the innovation is bad for the environment, then they are unlikely to consider it, and *Interviewee A4* considers that some clients can refuse to use a new material because they may believe that it is difficult to maintain or it takes more effort than usual. Finally, *Interviewee S* emphasized that in order to implement new materials people want to see how it works in Sweden and successful cases in other countries may not be admitted as a good argument, for example, due to the difference in climate and temperature. Those may differ in Sweden from those countries where this material is already in use, or generally not very conducive to innovation, which was argued by *Interviewee C3, S* and *Interviewee M4.* Another important barrier can be related to previous experiences as it was pointed out by *Interviewee S*:

> *"Nobody wants to be first. [...] But I think it is a fear of new materials. There's been a history, I would say in Sweden. In the 80s there was a time when people decided to build with what they call 'one step facade', so they just put finish directly on other materials such as ruffles. And it was a complete disaster. All of these buildings very, very soon had to be repaired or renovated or even torn down, and so there's a history in Sweden of when trying new things that they've had bad experiences."*

Negative occasions like these that happened 40 years ago, can still have an impact on today's behaviour. Something similar can also happen on a corporate level which was shared by *Interviewee A5*. There was a wooden construction project which failed which meant from then on, the company avoided working with wood and had to gain confidence to try it again. All of that shows that people might be more reluctant when they have experienced the cases when new techniques are implemented and do not work out as they should be. If the buildings had to be torn down or fixed, the companies had incurred a huge loss and damage and some might have suffered from reputation loss. As scenarios like these should urgently be avoided, it can automatically mean that firms avoid novelties completely.

Lastly, working with new material also means investing time. *Interviewee C3* is not ready to invest time to learn how to work with new material even if that was necessary. The interviewee added that due to the high workload, there was no additional time available that could be spent learning about new innovations. A similar statement was made by *Interviewee A2*.

6. Analysis

In the following chapter, the authors will present the analysis of the collected findings. The first part is about an analysis of the innovativeness of the Swedish construction industry. Subsequently, the barriers, are discussed which are categorized into independent and dependent variables. Then, the actions that have to be taken in order to conquer or unburden the identified barriers are elaborated. And lastly, the final section addresses conditions derived from the barriers and actions forming the ideal environment for a thriving innovation adoption process.

6.1 Innovativeness in the Construction Industry

The responses of the main study and the literature review like the study by Winch (2003) show that opinions regarding innovativeness in the construction industry vary. Some think the industry is quite innovative, others contradict them. But when it comes to the pace of innovation in the industry being slow, opinions seem to correspond. That is also aligned with the official data published by the *European Innovation Scoreboard* (2020). Apparently, Sweden has a leading position in terms of innovations in the construction industry but is especially weak regarding the sales of those innovations meaning they do not get implemented. Two different reasons could be recognized during the analysis. A slow adoption process can be one reason which was confirmed by multiple interviewees. The other one has to do with the high number of barriers that could be detected during the study. Those block the adoption process and harm the successful implementation. More details will be discussed in the subsequent section.

6.2 Barriers

There are a lot of barriers that negatively affect the innovation adoption process. Figure 7 gives an overview of the different barriers which can be put into two different categories: *independent* and *dependent barriers*.

The barriers with a solid line are the ones that are not directly influenceable, thus, they are called *independent barriers*. While it is possible to work around this type of barriers, the barrier itself cannot be controlled or reduced by any of the participants of the adoption process. Nevertheless, it is essential to be aware of those in order to counteract with measures and handle any potentially occurring difficulties well that might accompany those barriers. The other boxes with the dashed line are the opposite, therefore, referred to as *dependent barriers*. They imply that certain actions performed by the participants of the adoption process can have an influence, break through or at least mitigate those barriers in order to improve the adoption flow.

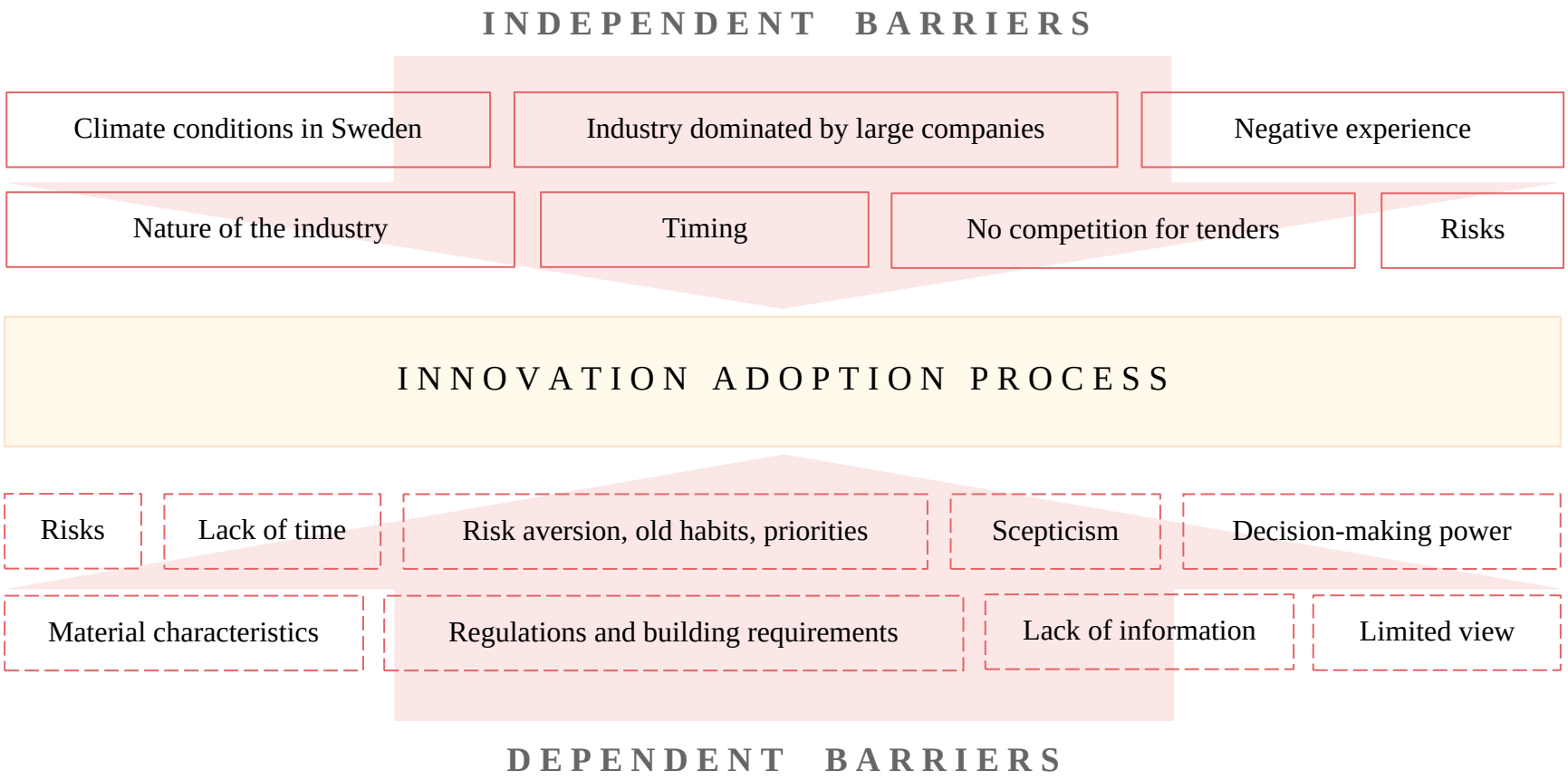

Figure 7: Framework "Barriers on Innovation Adoption", developed by the authors

It has to be stated that those barriers are not fixed components that always appear at certain stages. That means they are not part of every adoption process, but rather constitute potential hindrances that occur in different combinations at varying times of the different stages.

6.2.1 Independent Barriers

Climate conditions

One significant barrier is the climate conditions in Sweden. Those play a decisive role when it comes to building constructions, because factors like heat, coldness and weather conditions affect the requirements for the building and consequently also for the materials. That means for instance, not every material that is used in warm countries can automatically withstand the cold climate in Swedish regions. Those conditions cannot be influenced and have to be tolerated.

Industry dominated by large companies

The industry is dominated by large construction companies constitutes another hindrance. *Peab, Skanska* and *NCC* are the three big firms that control the market and set standards. Rearranging and retooling their production in order to implement new innovations is seen as being unprofitable. For start-ups that create new innovations, it is often a rather long process to capture the market if the three big companies do not follow initially which represents a barrier that cannot be changed.

Negative experience

The history of Swedish constructions also plays an important role, more precisely negative experiences. Two interviewees addressed the problem with certain techniques that were used unsuccessfully. One interviewee gave one example regarding a specific facade that was implemented in the 80s which had disastrous consequences as the buildings had to be repaired or even tore down after a short period of time after completion. Occurrences like this can be a reason why people in the industry tend to be risk-averse and reluctant towards unknown techniques and materials. As past experiences cannot be changed, that barrier is not influenceable.

Nature of the industry

Another barrier constitutes the nature of the industry. As it has been discussed before, it is a project-based industry that involves multiple different players. When so many different people and companies are involved, it becomes very difficult and sometimes almost impossible to make changes in different processes, including introducing innovations. The high number of people and companies involved in one project resulting in increased complexity is part of the industry and cannot be changed.

Timing

Timing can have a positive influence on the innovation adoption process. The over the last couple of years increased awareness towards environmental issues which was also discussed in section 2.5 can push innovative solutions. On the contrary, a lack of such a movement can also harm the adoption. Several years ago, the successful sales of those innovative and green products would have been more complicated due to the lack of awareness. If the demand for those materials does not exist and people do not occupy themselves with the subject of sustainability, there is no obvious need that prevents the adoption from happening. In summary, the timing of introducing a new innovation has a huge impact and can also have a negative effect.

No competition for tenders

The barrier concerning tenders only affects one group of adopters, namely the municipalities. It has to do with the fact that municipalities often use public tendering for various projects inviting companies to make a proposal. But according to provisions that can only take place if more than one company is on the market that is suitable for the tendering. If that is not the case, the municipality has to choose a different way which might automatically exclude certain companies.

Risks

Risks playing a role when talking about new innovations is nothing new as it was noticed in literature by Seaden, Doutriaux & Nash (2003). In this study, two risks could be identified that are independent and cannot be mitigated or overcome and therefore, have to be tolerated. It concerns the longevity and future maintenance of the innovative material. The goal is to use as long-lasting materials and products as possible to build sustainable constructs. But as testing phases cannot take place over decades, it is difficult or even impossible to ensure and prove longevity. It is similar to the maintenance issue as no one can predict the effort it takes to maintain the material in the far future. That is why it has to be accepted that with new innovations, some risks have to be taken. On the other hand, there are also risks that do not have to be fully accepted but can be influenced and even erased by different players which will be elaborated in the next chapter.

6.2.2 Dependent Barriers

Risks

One central barrier that affects multiple different areas is the risks the adopters have to take. As the survey results showed (see Appendix B - Survey Questionnaire “Potential Adopters” and Results), most of the interviewees assessed the risk of working with new innovative materials on a medium to a high level which proves the significance of that barrier.

The first one is about the uncertainty of potential failure which can always happen due to multiple different reasons and as consequence harm the reputation of the company. A negative outcome of a project can lead to losing clients, revenue and their skills and competence getting questioned. Therefore, the business can be damaged immensely which is hard to recover from. That risk is present in every project, but for new innovations it means working with more uncertainty which leads to a higher risk level. The extent of the innovation also plays a role. If only a small proportion of the whole construction building consists of the new innovation, the risk is small. If something goes wrong, the damage would be tolerable. Presuming every component would be a new innovation, the risk would increase immensely. It can also have to do with the purpose of the material or product. Paint colour for instance that is a design element is easily replaced without making a big loss. Implementing a new material for the walls implies a bigger risk and is connected with larger and more costly consequences in case of failure. Lastly, there is the risk that the ordered supply cannot be delivered. Especially with suppliers that are new on the market and therefore small, the risk is higher. If the supply is not secured, the project could fail.

Lack of time

The lack of time on the part of the adopter can also be a hindrance. Evaluating and then implementing new innovations implies investing additional time. Engineers need to learn how to do the calculations, architects need information regarding the optics and so forth, the consultant needs to acquire information regarding for instance regulations, certifications and physical properties and construction workers need to learn techniques on how to work with it. But if no additional time is available or the willingness does not exist, the adoption of new innovations is in danger.

Risk aversion, old habits and priorities

Being risk-averse, sticking to old habits and following certain priorities are traits that can prevent a successful innovation adoption from happening. Risk aversion can impede someone from trying out new things. That can be applied to implementing a new material. If no one wants to take the risk, there will not be any change and new innovations have no chance on the market. Old habits are about convenience. As Moore (2014) pointed out, conservatives like to stick to things that work for them. That has to be overcome in order to successfully implement new innovations. Priorities also have an impact. The construction industry is money-driven and that is reflected in the priorities. One interview participant said the first question regarding new materials is about the cost, the second about the qualities. With new and especially green innovations, the qualities add a lot of value. If those are deferred, the potential might not be seen and the innovation gets refused.

Scepticism

The next barrier is similar to the previous one as it has to do with the personal view. A lot of people are sceptical at the beginning towards new innovations. If proof is not provided, the promised features and characteristics might not be trusted, and the distrust overweighs. Especially the fact that Sweden has specific climate conditions demands for a proof of concept. In the worst case, the new innovation does not get adopted, because the adopter does not have enough confidence in the innovation.

Decision-making power

Another barrier addresses the distribution of responsibilities. One interviewee pointed out that all the different players involved in a project need to agree to work with a new innovative material. That means the innovation has to run through a process, from the idea until the actual usage which is connected with a huge number of decisions that have to be made. Another interview participant mentioned that architects do not have enough power to decide on certain issues, but rather have to convince the decision-makers. All of that has to do with the level of involvement of the project participants and contract designs which was also addressed by Blayse & Manley (2004) who suggest involving the clients more. If the *right* people that want to implement new innovative materials do not have enough power to pull it off, it is more difficult to adopt new innovations.

Material characteristics

There are multiple different requirements that have to be met in order to implement new innovative materials. Those demands vary depending on the adopter and her/his priorities meaning not every adopter requests the same characteristics. But not fulfilling one could mean the material gets rejected by the potential adopter. The requirements that could be collected through the interviews include the status of testing, certifications and databases, opportunity costs, the price, maintenance costs, the environmental impact and governmental regulations and requirements.

As the testing capabilities or possibilities of the adopters can be quite low or even non-existent, a lot of them expect that the material has been tested previously and therefore, rely on the judgment of third parties, and the main reason is proof of concept. People want to see how the material behaves and if it works in Sweden. If the testing did not happen, the process of adopting could be postponed or even instantly rejected. That refers to the innovation characteristic by Rogers (2003) trialability. Trialability is about to which extent the innovation can be tested. In the construction industry, that depends on the prospective company as it is their decision to what extent the innovation gets tested. Testing is also connected with certifications that assess the materials on various dimensions and databases that offer a list of tested products and materials. As some interviewees emphasized that in order for them to

consider new materials, those have to be qualified by certain certifications or listed in specific databases. Not certifying materials and not listing them in these systems can result in refusal on the part of the adopters.

As money plays a central role in the construction industry, new solutions should not cost more than the current ones, because the budgets are limited. The comparison with current solutions also has to do with the relative advantage (Rogers, 2003), where the adopter wants to see the benefits of the innovation compared to other solutions. In this case, it is about the price benefit. Hence, declining a new innovation can derive from high opportunity costs meaning higher costs compared to alternatives. Maintenance costs are another barrier and include the actual costs and the effort it takes to maintain the material. If those costs are high, it negatively affects the assessment of the innovation as those costs want to be avoided. Scenarios like these can end up in rejection of the material.

A requirement increasing in its importance is about the environmental aspects of the material. A lot of adopters refuse innovations that have a negative impact on the environment. Lastly, one essential point is the regulations and building requirements. As those are set by the government or municipalities, there is no way around them. As new regulations and provisions are released regularly, constant monitoring from the suppliers is necessary to ensure that the offered material meets these.

Regulations and building requirements

The regulations that were already mentioned in relation to the material characteristics can constitute another barrier. Two interviewees stated that the Swedish construction industry is so highly regulated that there is not enough room for new innovations. With a strict legislation system, potential adopters struggle to adopt new innovations. More information regarding the Swedish regulation system was provided in section 2.3.

Lack of information

Especially at the beginning of the adoption (awareness stage), misjudgements and negative assumptions can arise if not enough information is available. The first one has to do with the specificities of organic materials. As one interviewee stated, people are reluctant towards organic materials as they can develop a problem with moisture leading to fungi. That does not automatically mean that that is the case for every material. Still, there is a presumption that could be hard to erase. Negative assumptions can come up if the person is not sufficiently informed. One interviewee questioned the versatility of hempcrete and only sees its usage in specific projects, another one mentioned greenwashing. If material is stamped and no further research is done, those presumptions could spread and lead to multiplied rejection of the material. In the stage of implementation, as working with new materials implies absorbing new

knowledge, a lot of different types of information tailor-made for the adopters is required in order to be able to do that. If that information is missing or not provided sufficiently and of high quality, the adoption cannot take place in an organized and successful matter.

Limited view

One other important barrier is the restricted views regarding costs and energy performance. Often, when the costs are calculated, the only costs that are taken into account are the price that has to be paid for the material. The costs that derive from man-hours and project duration that differ depending on the materials that are worked with are not taken into consideration. But those factors have an impact on the overall costs. If only certain aspects are looked at like the price of the material that needs to be as cheap as possible, then other important elements are ignored which distorts the overall result. Regarding the energy performance calculations, for instance, the energy that is used in order to extract the raw materials, to manufacture and deliver them are ignored. But those are part of the construction and require inclusion and consideration.

6.3 Overcoming the Barriers

This chapter focuses on the specific actions that can be performed to overcome the barriers that have been described in the previous section. The actions are divided according to the respective performer: adopters, suppliers and the government.

Adopter's Actions

1) Establish a sustainable business strategy

   The first action that will be discussed has to do with the companies' alignment with sustainability and new innovations. If the employees simply do not have the opportunity to invest time in order to learn more about and deal with new material, they are restricted within the company in terms of freedom. It is the responsibility of the company's management to create an environment that leaves room for those actions. That should be about establishing an overall sustainable corporate strategy and mission that includes enough free space to handle those issues. Thereby, it is essential to implement sustainability connected with the business and not as a separate strategy. Figure 8 illustrates the relationship between the barrier and the action. A similar approach was elaborated by (Blayse & Manley, 2004) which referred to organizational requirements that benefit innovation.

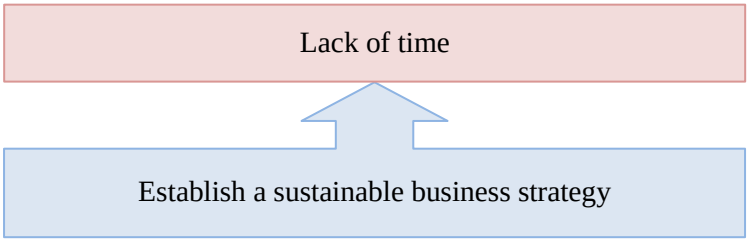

Figure 8: Adopter's action 1)

2) Follow a holistic and long-term approach

The fifth action that has to do with the management targets the type of view with regard to assessment. As it was previously mentioned in the findings, some people look at and calculate the benefits and risks of new material with a short-term view. Thus, they may miss out on good materials that show their benefits in the later stages of the project. At the same time, they run the risk of using the material that shows excellent performance in production and the construction process but has a bad performance during maintenance and after the project is finished. Similar is the view regarding the energy performance, as it is also rather limited than holistic. Often, the energy performance of the finished construction is analysed, but the whole building process and the life span of the building are not included. Excluding those factors when calculating the energy performance does not mirror the true results. Therefore, in order to avoid such mistakes and not reject the material due to the fact that erroneous conclusions were made about it, the calculations of the costs and the energy performance should be done with a more holistic and long-term approach (Figure 9).

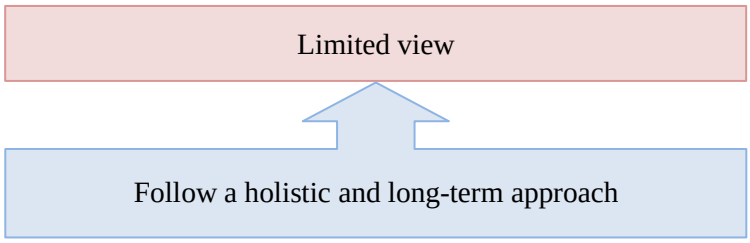

Figure 9: Adopter's action 2)

3) Customise the contracts

Another point that has to be discussed is legal issues that influence decision-making power. A similar finding was also pointed out by (Blayse & Manley, 2004) who declare contracts often being conservative and therefore blocking innovations. In this case, it is about responsibility distribution. If contracts would be designed in a certain way that allows people who want to implement new innovative and green materials to be in charge, then the adoption could be easier and take place faster as the decision-making authorities' opinions regarding the environment agree. It does not depend on the

position of the person, but rather on their attitude towards sustainable innovative solutions and their vision to build more sustainable. That implies that contracts should not be standardised but rather customised depending on the respective project members (Figure 10).

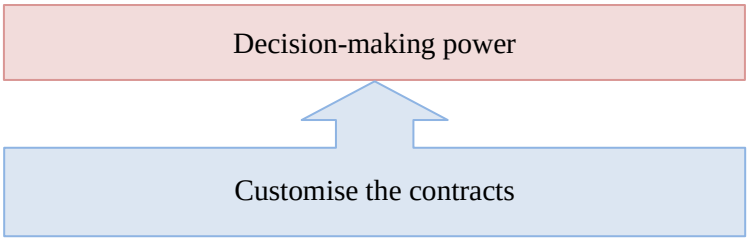

Figure 10: Adopter's action 3)

4) Test the innovations

This action has to do with the proper evaluation of a new innovation. While some companies-adopters already use this type of material assessment, it is suggested that other companies that avoid using new materials due to various risks also begin doing testing. Testing is not part of the company's commercial projects, and therefore the risks are significantly lower than when the material is immediately implemented partially or in full (Figure 11).

5) Introduce partial or gradual implementation

Another action deals with the implementation process, where different strategies can be followed. The first option is that adopters can reduce the overall risk of innovation by gradually implementing it to the projects. This means that instead of introducing innovation into all new projects at once, it should be introduced in small, less significant projects. The second option is about doing the partial implementation. It is worthwhile to start using the innovation in some parts of the building or in one building that is part of a complex (Figure 11). The overall risks are much lower than fully implementing it.

6) Secure a plan b

Another part of the companies' management is about having a plan b. As one of the risks of innovation adoption some respondents mentioned that there is a possibility that the company providing innovation will not be able to provide the required amount of supply. This concern is not unfounded, since innovations are usually provided by new companies without a large customer base, and therefore, initially, while the company is just entering the market, the supply is not prepared for large quantities. In this regard, adopters should find out in advance if there are alternative companies on the market offering a similar solution, in order to contact them if problems arise with the original

supplier. The fear of supply bottlenecks should not keep a client from choosing a smaller start-up, but instead, alternative solutions should be deliberated and planned (Figure 11).

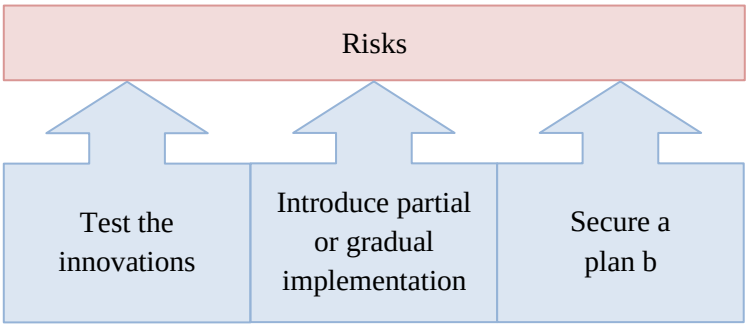

Figure 11: Adopter's action 4), 5) and 6)

7) Become more open and set different priorities

The last action that is the responsibility of the adopters targets the personality and addresses three barriers at the same time. This time not only the people that work for the industry are considered, but also the buyers. To reduce the number of barriers between the adopter and new innovations, in some cases it is necessary to change the mindset of potential users. Some potential adopters focus on the wrong priorities such as money, follow old habits and they like to stick to or/and are extremely afraid of taking any kinds of risk. That not only prevents them from trying new materials, but in general, can harm their business. These kinds of adopters need to open up to receiving new information, accepting trends, setting their priorities newly and weigh the pros and cons of new innovations more often (Figure 12).

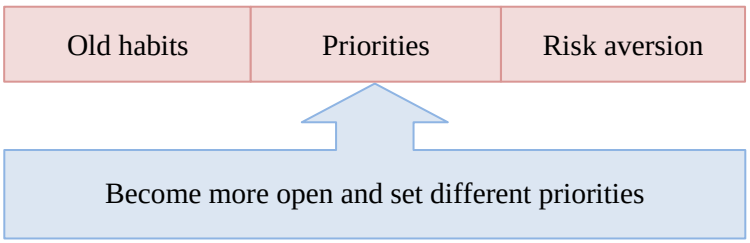

Figure 12: Adopter's action 7)

Supplier's Actions

1) Provide relevant information

Knowledge transfer is important at every stage of the adoption process. In the very beginning, it is necessary in order to catch the attention of the potential adopter and to avoid misconceptions or prejudices. Following the closer investigation, information

including all sustainability aspects should be provided in order to give a holistic overview. Regarding the evaluation followed by the implementation, the supplier must ensure that all potential adopters have the ability to access a reliable source that will provide all the information about the material that may be needed when deciding on its implementation or when directly using it. It is desirable that this is a single and comprehensive source that inspires the confidence of potential users. The supplier can also provide relevant information to the adopters by organizing various events, such as workshops. This will help ensure that potential adopters have complete and correct information about the material, dispelling rumours and misconceptions, and reducing the disinformation inherent in innovations (Figure 13).

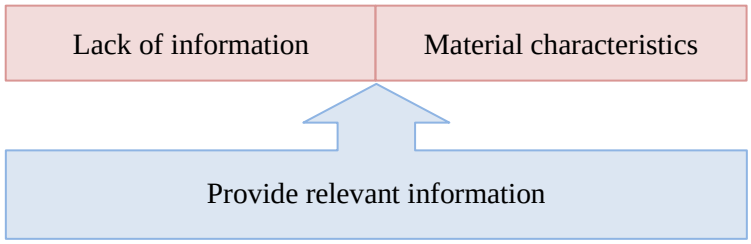

Figure 13: Supplier's action 1)

2) Get the innovation certified and added to relevant databases

Multiple times during the interviews the views were expressed that in order for a company to start using new material, it must have a certain certification or be included in the relevant databases. In addition to the fact that the presence of this criterion is very desirable and important, some respondents mentioned that this material characteristic is a mandatory requirement for them. Thus, the supplier of the material must ensure that the material has received appropriate market certifications and that it is listed in the relevant databases (Figure 14). Examples of certificates and databases that are common in Sweden were described in section 2.4.

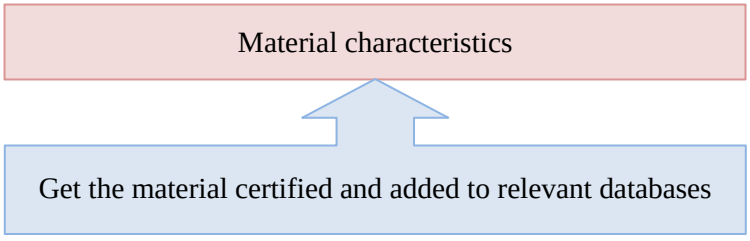

Figure 14: Supplier's action 2)

3) Offer successful showcases

Another way a supplier can increase the chances of new material being adopted is to create and demonstrate successful use cases for the material. Many respondents stressed that one of the key factors for them is whether there are already use cases for the

material in the market in which they operate. Additionally, showcases, where the adopter can see and even feel the innovation, can help to reduce or even eliminate scepticism. Thus, in the context of this study, the supplier needs to create and show potential users a successful project using the new material in Sweden (Figure 15). Proof of concept in terms of showcases also suits Roger's (2003) innovation characteristic observability. It talks about the degree of visibility of the outcome of the innovation. With showcases, the outcomes are observable to the most extent possible if the supplier chooses to show the hempcrete wall in its natural appearance which differs from the other solutions.

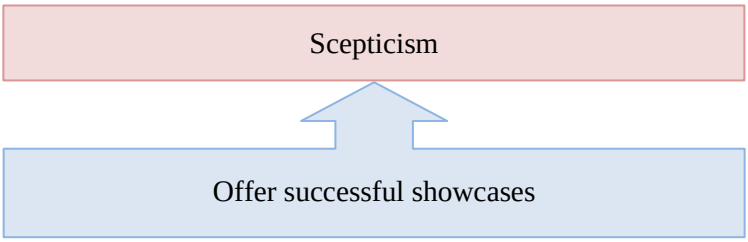

Figure 15: Supplier's action 3)

Government's Action

1) Reconsider and adapt a current regulation system

For the final action, the government is responsible. The Swedish environment in the construction field is highly regulated. When adopters are too restricted, because the standards are very high. On the other side, the government could also be stricter in terms of environmental impact and put more pressure on the companies to act. Setting goals and limits can force companies to be more active. Governmental interventions and actions should be reconsidered, partly loosened and adapted in order to create an environment that allows companies to test and implement innovations more easily and smoothly (Figure 16). That policy instruments can drive innovation was also mentioned by Bossink (2004). With that action, the government would not only support the companies in the construction industry, but also push the economic growth in the country resulting from innovations (Blayse & Manley, 2004).

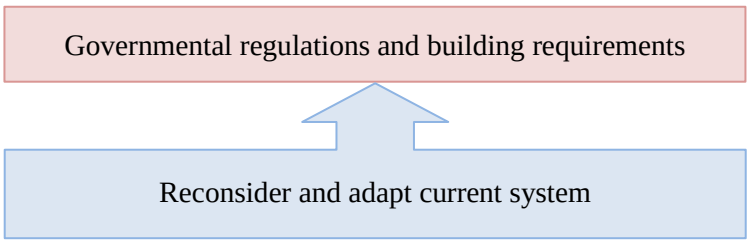

Figure 16: Government's action

6.4 Creating Ideal Conditions

In order to combine and summarize the collected barriers and the developed actions, the authors came up with six different conditions that create the most favorable environment for a successful innovation adoption process. An overview of where the conditions derived from, can be seen in Figure 17.

The first one addresses the issue with the risks. As working with new innovation implies taking a risk but adopters seek as low risks as possible due to the high financial capital involved, *(1) mitigated risks* mean a higher willingness for innovation adoption. Another condition is constituted by a *(2) sustainable business management*. As the adopter company represents the place where new innovations get adopted, the whole company should embody sustainability and create an environment that facilitates the work with new innovations. An *(3) open mindset* is also an extremely important condition as adopting novelties requires a certain degree of openness. Next, *(4) sufficient knowledge transfer* should be ensured, which means that the adopter must have enough appropriate information to form an opinion about innovation without any misjudgements and to be able to work with it. Building and presenting the successful cases of implementation of innovation in the market in which potential adopters are operating, enables to create *(5) proof of concept* and therefore significantly increases the number of the adopted units of innovation due to confidence-building and reducing uncertainty in relation to innovation among potential adopters. And last but not least, *(6) effective policy-making* should allow local regulations not only to secure safety and competition in the industry, but also to ensure that, in the current environment, industry players are able to test and introduce new products without breaching legislation.

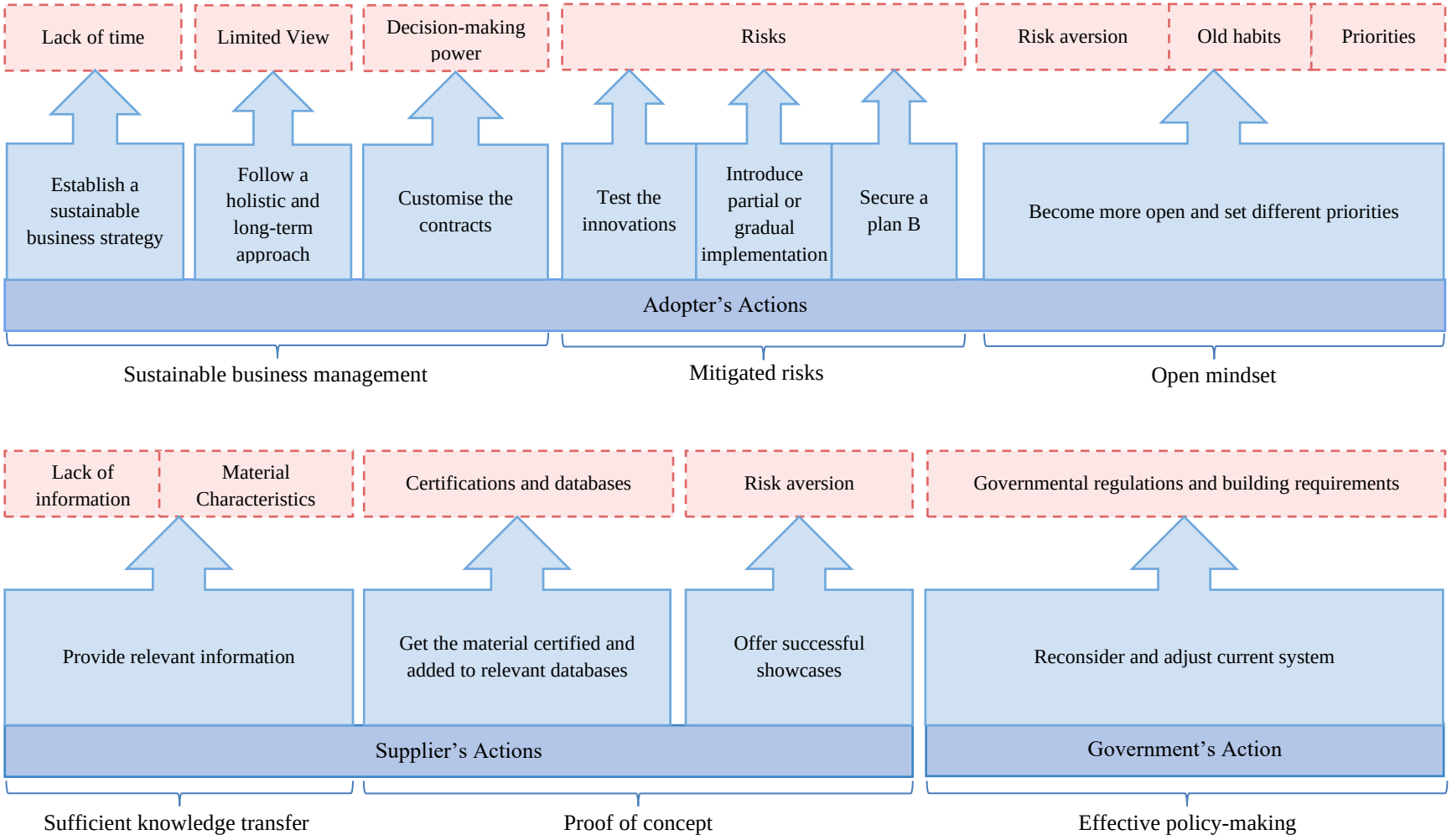

Figure 17: Overcoming barriers by actions resulting in conditions

7. Conclusion

This chapter of the study is divided into five parts. The first section talks about the overall accomplishment of the study, 7.1 discusses the linkages between the objective of the study and the results by answering the research questions. In the third section, the two researchers make research proposals for future work. Concluding with the contributions, the two authors elaborate on how the conducted research study contributed on a theoretical and also on a practical level.

This research was focused on examining the adoption process of innovative eco materials in the construction industry in Sweden. As a result of the research process, the authors were able to determine how various industry participants can foster the innovation adoption process of eco materials in the Swedish construction sector. To accomplish that, the authors first examined what the barriers are that negatively influence the process of innovation adoption. Later, the researchers defined the actions that can contribute to the elimination of these barriers and identified which of the industry participants should take these measures. The combination of the above findings leading two conditions provides an opportunity to create the most supportive environment for the adoption of innovations within the area of the current study. Based on the results of this study, not only the supplier of the new material can push forward the innovation adoption process, but also the government and adopters themselves.

7.1 Answering the Research Questions

In order to answer the main research question, two sub-questions were designed for a structured investigation. Consequently, before answering the main research question, the answers for the two sub-questions will be presented.

***RQ a**: What are the barriers that influence the adoption process of new eco innovative materials within the construction industry in Sweden?*

Since the main aim of this study was to research how the innovation adoption process of eco materials in the Swedish construction industry can be fostered, it was crucial to study the influencing elements (hereinafter barriers) that have a negative impact on this process and obstruct and block it. Barriers are a determining factor in whether the innovation adoption process will be triumphant or unsuccessful, and they can be either dependent or independent. This means that the level of influence of some of them may depend on the actions of participants in the construction industry (dependent barriers), and vice versa, some of the

barriers are not conditional on the behaviour of industry participants (independent barriers). To give an overview, the researchers created the Framework *"Barriers on Innovation Adoption"* (see Figure 7 summarized in Table 7) identifying and describing the *barriers* on the adoption process.

Barriers	
Independent	Dependent
- Climate conditions in Sweden - Industry dominated by large companies - Negative experience - Nature of the industry - Timing - No competition for tenders - Risks	- Risks - Lack of time - Risk aversion, old habits, priorities - Decision-making power - Material characteristics - Restricting regulations and building requirements - Lack of information - Limited view - Scepticism

Table 7: Independent and dependent barriers

***RQ b**: How can the barriers of the adoption process of the eco innovative materials be overcome?*

The second sub-question addresses how the identified barriers can be overcome. As it has been discussed, there are dependent (influenceable) barriers harming the innovation adoption process. But it is possible to overcome these by performing certain actions which have been identified by the two authors. The actions that are necessary in order to secure or improve a successful adoption and overcome or mitigate the identified dependent barriers, were presented in the Framework *"Overcoming barriers by actions resulting in conditions"* developed by the authors (see Figure 17, summarized in Table 8). The actions are outlined that any of the three actors – *suppliers, the government* and *innovation adopters* – can take to help overcome barriers that negatively impact innovation adoption.

Adopter's Actions	Overcome or mitigated dependent barriers
1) Implement a sustainable business strategy by offering the employees the possibility to work with new innovations	Lack of time
2) Create a test bed such as a lab to enable testing possibilities	Risks
3) Introduce partial or gradual implementation by using the material only for small projects or one small fraction of a bigger project and implement only one new innovation in one project	
4) Make sure an alternative supply is secured and other suppliers are able to deliver similar materials in case of delivery problems	
5) Have a more holistic and long-term approach by including the future component in assessment techniques	Limited view
6) Establish customized contracts that appoints the decision-making power to people that are driven by sustainability	Decision-making power
7) Change the mindset in terms of being open-minded, less risk averse and more willing to work with new innovation	Risk aversion Old habits Priorities
Supplier's Actions	**Overcome or mitigated dependent barriers**
1) Provide the adopter from the very beginning until the confirmation stage with all the relevant information in a sufficient and convenient way to allow an effective knowledge transfer	Lack of information Material characteristics
2) Make sure the material is certified and listed in relevant databases	Certifications and databases
3) Offer showcase projects to show proof of concept to the adopter	Scepticism

Government's Action	Overcome or mitigated dependent barrier
1) Reconsider the current system and create a regulation system that allows enough room for adopting new innovations	Governmental regulations and building requirements

Table 8: Overview of actions and overcome barriers

***RQ**: How can the innovation adoption process of eco materials in the Swedish construction industry be fostered?*

Lastly, with the answers to the two sub-questions, the authors were able to also give an answer to the main research question. With six different conditions that were identified by the two authors, an environment can be created that fosters the innovation adoption process which also gives a broader overview (see Table 9). Those conditions include mitigated risks which increase the willingness of actors to adopt, sustainable business management which facilitates the adoption process for adopters, an open mindset by the adopters, sufficient knowledge transfer provided by the supplier, a proof of concept which is also the suppliers' responsibility and effective policy-making executed by the government. An overview is given by the following table, where each pillar represents one condition:

Fostered Innovation Adoption Process					
Sustainable Business Management	Mitigated Risks	Open Mindset	Sufficient Knowledge Transfer	Proof of Concept	Effective Policy-making
Adopter			Supplier		Government

Table 9: Overview of the ideal conditions for a fostered innovation adoption process

7.2 Suggestions for Future Research

The results of this study give rise to further research and ideas to continue the development of the discussed topic. For example, the authors of this research focused solely on the adoption

process of innovative eco materials in the Swedish construction industry, which means that more extensive research can be done on the adoption of any innovative material or product. Future research can also be done on taking a closer look at how the innovation adoption barriers can be overcome, in particular, how the proposed actions can be actually implemented. Although this study has already identified the actions, the authors believe that more detailed research should be done in order to define the specific strategies.

Another point is about transferring the study to another context. The authors of this research consider that the results can be applied to a wider area. It was emphasized that the study was more aimed at examining the adoption of low-tech innovative materials, however, the authors believe that the findings can be suitable for the implementation during the adoption of innovative high-tech materials. Likewise, despite the fact that the study was limited to examining the Swedish construction market, in some cases, consideration may be given to applying the results also to Nordic countries as these show a lot of similarities to Sweden or even to some European countries. It should be noted that applying the results of this study to the above should be considered a good start and help, however, they cannot be applied with complete confidence without doing more in-depth and further research.

7.3 Theoretical Contributions

Firstly, elements could be detected that influence the adoption phases in a positive or negative way. As part of the study, barriers that block or harm the process of adopting new innovations, could be identified. The resulting framework gives an overview of the negative forces that impact the adoption process of eco innovative materials in the construction industry. Those barriers were divided depending on their suggestibility. The independent barriers are not influenceable, whereas dependent barriers can be affected, namely by actions performed by three different actors - adopters, suppliers and the government.

The second essential contribution is about the developed actions. Those were identified in order to allow a successful adoption or at least improve the process. Those activities that have to be performed by the adopters address the personal mindset, strategies, management, approaches and legal issues. Certain assessment requirements and knowledge transfer are included in the activities performed by the supplier and lastly, the government is responsible for the transformation of the regulation system.

Thirdly, the six conditions that were identified by the two authors serve as guidance for an ideal environment for a successful innovation adoption process. In contrast to the barriers and actions that are mainly applicable to the construction industry, because they are specifically designed

for the players, the authors assume that the conditions are also relevant for every other industry. The reason for that is that the conditions are defined broadly creating a universal environment.

In summary, the results provide a more precise and detailed understanding of the innovation adoption process in the Swedish construction industry for green materials and can serve as a basis for future research.

7.4 Practical Contribution

The authors not only contributed on a theoretical basis with the conducted research study, but also with practical advice. For the players in the market, it is essential to know what kind of elements influence the adoption process. The revealed barriers are important to know in order to secure a faster and more efficient innovation adoption process as the examined actions can help to either prevent or mitigate the barriers. All of these activities are not described in detail as it goes beyond the scope of the study and depends on the particular performer, but they provide a basis and an initial concept for the actors that can further be developed. The responsibility to actually perform these actions is spread among three different groups in the construction industry: suppliers, adopters and the government.

For material suppliers such as the company *House of Hemp* that is new to the market and therefore at the beginning of the innovation diffusion process, the provided and discussed insights of this study can help to further develop an improved business strategy. Considering all the barriers and the three proposed actions for approaching potential users, the adoption process can become more effective. With the actions that were developed by the authors, not only material suppliers, but also adopters can contribute to foster the adoption process in order to achieve a more innovative industry. With seven different suggested actions, the adopters can make a significant contribution that not only fosters the company itself, but also the whole industry. The third group that can make a big impact is the Swedish government. With a decisive action, the whole industry would be affected, and the innovation adoption process could be accelerated.

Lastly, it has to be mentioned that the two authors contributed to spreading awareness towards the implementation of new innovations among different players in the construction industry. As a high number of interviews took place, the authors called attention to the topic and inspired and stimulated the thoughts of the players. With the several requested sharing of the thesis, it can be stated that the general interest is high which hopefully might lead to more future actions.

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GHG	Greenhouse Gas
OECD	Organisation for Economic Co-operation and Development
BREEAM-SE	Building Research Establishment Environmental Assessment Method - Sweden
CEEQUAL	Civil Engineering Environmental Quality Assessment and Award Scheme
LEED	Leadership in Energy and Environmental Design
BRE	British Research Establishment
ICT	Information Communication Technology

Bibliography

Allerup, J. (2020, October 26). *Natur Vårdsverket*. Retrieved March 2021, from http://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedish-environmental-work/Work-areas/Climate/Climate-Act-and-Climate-policy-framework-/

Amziane, S., & Arnaud, L. (2013). *Bio-aggregate-based Building Materials: Applications to Hemp Concretes.* UK & USA: ISTE Ltd and John Wiley & Sonc, Inc.

Baregheh, A., Rowley, J., & Sambrook, S. (2009, September 4). Towards a multidisciplinary definition of innovation. *Management Decision, 47*(8), pp. 1323-1339.

BASTA. (2021). Retrieved 2021 April, from https://www.bastaonline.se/sa-fungerar-det/produkter-i-basta/

BCB Tradical. (2021). Retrieved from https://www.bcb-tradical.com/en/about-us/

Bedliva, H., & Isaacs, N. (2014). Hempcrete - an environmental friendly material?

Beiser, V. (2017, February 27). *The Guardian*. Retrieved February 2021, from https://www.theguardian.com/cities/2017/feb/27/sand-mining-global-environmental-crisis-never-heard

Bell, E., Bryman, A., & Harley, B. (2019). *Business Research Methods.* Oxford: Oxford University Press.

Blackley, D. M., & Shepard , E. M. (1996, December). The Diffusion of Innovation in Home Building. *Journal of Housing Economics, 5*(4), pp. 303-322.

Blayse, A., & Manley, K. (2004). Key influences on construction innovation. *Construction Innovation, 4*, pp. 143-154.

Bossink, B. A. (2004, June 1). Managing Drivers of Innovation in Construction Networks. *JOURNAL OF CONSTRUCTION ENGINEERING AND MANAGEMENT, 130*(3), pp. 337-345.

Boverket. (2018). *Regulatory hierarchy - from law to general recommendation*. Retrieved 04 2021, from Boverket: https://www.boverket.se/en/start/building-in-sweden/swedish-market/laws-and-regulations/national-regulations/regulatory-hierarchy/

Boverket. (2020). *About the National Board of Housing, Building and Planning*. Retrieved 04 2021, from Boverket: https://www.boverket.se/sv/om-boverket/

Boverket. (2021, February 01). Retrieved April 2021, from https://www.boverket.se/en/start/building-in-sweden/developer/rfq-documentation/climate-declaration/questions/

Boverket. (2021, March 24). Retrieved April 2021, from https://www.boverket.se/en/start/building-in-sweden/developer/rfq-documentation/climate-declaration/environmental-certification/

Byggvarubedomningen. (2021). Retrieved April 2021, from https://byggvarubedomningen.se/in-english/

Cambridge University Press. (2021). *Meaning of low-technology*. Retrieved 2021 04, from Cambridge University Press: https://dictionary.cambridge.org/de/worterbuch/englisch-deutsch/low-tech

Christensen, C. M., Anthony, S. D., & Roth, E. A. (2004). *Seeing What's Next: Using the Theories of Innovation to Predict Industry Change.* Boston: Harvard Business School Press.

Collet, F., & Pretot , S. (2014). Thermal conductivity of hemp concretes: Variation with formulation, density and water content.

De Best, R. (2018). *Global green building materials market in 2018, with a forecast for 2024*. Retrieved February 2021, from Statista: https://www.statista.com/statistics/587718/green-building-materials-market-outlook-worldwide/

De Best, R. (2020, December 16). *Statista*. Retrieved February 2020, from https://www.statista.com/statistics/314988/leading-buildinc-material-manufacturers-worldwide/

De Best, R. (2020, November 3). *Statista*. Retrieved February 2021, from https://www.statista.com/topics/2983/construction-materials-industry/

De Best, R. (2021, January 27). *Statista*. Retrieved 2021 March, from https://www.statista.com/statistics/880055/leading-construction-and-building-companies-in-sweden-by-turnover/

De Best, R. (2021, January 7). *Statista*. Retrieved February 2020, from https://www.statista.com/statistics/195382/us-producer-price-index-of-construction-materials-since-1990/

De Valence, G. (2018, September). Reframing construction within the built environment sector. *Engineering Construction & Architectural Management, 26*(5), pp. 740-745.

Dearing, J., & Cox, J. (2018). Diffusion on Innovations Theory, Principles, And Practice.

Eng, T.-Y., & Quaia, G. (2008). Strategies for improving new product adoption in uncertain environments: A selective review of the literature.

Environdec. (2021). Retrieved April 2021, from https://www.environdec.com/all-about-epds0/all-about-epds

EU Ecolabel. (2021). Retrieved April 2021, from https://eu-ecolabel.de/

Europäische Kommission. (2021). Retrieved April 2021, from https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_de

European Commission. (2020). *European Construction Sector Observatory: country profile Sweden.*

European Commission. (2020). European Construction Sector Observatory: Country profile Sweden.

European Commission. (2021). *Construction*. Retrieved 04 2021, from European Commission: https://ec.europa.eu/growth/sectors/construction_en

European Innovation Scoreboard. (2020, June 22). *European Comission.* Retrieved April 2021, from https://ec.europa.eu/docsroom/documents/41892

Global Industry Analysts, Inc. (2020). *Construction Materials - Global Market Trajectory & Analytics.* Research and Market.

Göteborgs Stad. (2021). *Hoppet - ett innovationsprogram för fossilfri byggnation*. Retrieved 05 2021, from Göteborgs Stad: https://goteborg.se/wps/portal/enhetssida/hoppet-fossilfri-byggnation/fragor---svar

Göteborgs Stad. (2021). Retrieved from Klimatstrategiskt program för Göteborg: https://goteborg.se/wps/portal/start/miljo/det-gor-goteborgs-stad/klimatstrategiskt-program?uri=gbglnk%3A20121204-151042

Hardie, M. (2009). CONSTRUCTION INDUSTRY CULTURE AND INNOVATION: AN AUSTRALIAN VIEW.

Hosseini, M. R., Chileshe, N., Zuo, J., & Baroudi, B. (2016). The status quo of innovations within the construction industry: a conceptual model. *Int. J. Project Organisation and Management, 8*(3), pp. 217-239.

Islam, T. (2014, February 2014). Household levelinnovationdiffusionmodelofphoto-voltaic(PV)solar cells fromstatedpreferencedata. *Energy Policy, 65*, pp. 340-350.

Kemp, R., & Pearson, P. (2007). *Final report MEI project about measuring eco- innovation.* DG Research of the European Commission, Eurostat, the European Environment Agency (EEA) and the Joint Research Center (JRC) of the European Commission, Brussels.

Khatatbeh, A. (2021, March 9). Using a Mixed-methodology to assess innovativeness and adoption of new practices in engineering management in construction industry. *International Journal of System Assurance Engineering and Management*.

Kleijnen, M., Lee, N., & Wetzels, M. (2009). An exploration of consumer resistance to innovation and its antecedents.

Koebel, C. T., McCoy, A. P., Sanderford, A. R., Franck, C. T., & Keefe, M. J. (2015, June 15). Diffusion of green building technologies in new housing construction. *Energy and Buildings, 97*, pp. 175-185.

Kohli, A., & Jaworksi, B. (1990). Market Orientation: The Construct Research Propositions, and Managerial Implications.

Korstjens, I., & Moser, A. (2017, December 05). Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *European Journal of General Practice, 24*(1), pp. 120-124.

Laukkanen , P., Sinkkonen, S., & Laukkanen , T. (2008). Consumer resistance to internet banking: postponers, opponents and rejectors.

Lehne, J., & Preston, F. (2018). *Making Concrete Change Innovation in Low-carbon Cement and Concrete.* Energy, Environment and Resources Department. London: Chatham House, the Royal Institute of International Affairs.

LFM30. (2021). Retrieved March 23, 2021, from https://lfm30.se

Lhoist Southern Europe BCB. (2016). Tradical Hempcrete Brochure.

Miller, S. A., Horvath, A., & Monteiro, P. J. (2018, January 8). Impacts of booming concrete production on water resources worldwide. *Nature Sustainability, 1*, pp. 69-76.

Mistra Carbon Exit. (2021). Retrieved April 2021, from https://www.mistracarbonexit.com/our-research

Moore, G. (2014). *Crossing the Chasm: Marketing Selling Disruptive Products to Mainstream Customers.* New York: Harper Business.

Moore, G. A. (2014). *Crossing the chasm: Marketing Selling Disruptive Products to Mainstream Customers* (3 ed.). New York: HarperBusiness.

Nordic Ecolabel. (2021). Retrieved 2021 April, from https://www.nordic-ecolabel.org/certification/ecolabelled-buildings2/for-license-holders-and-applying-companies/

OECD. (2019). *Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences.* Paris: OECD Publishing,.

Oyedele, A., Owolabi, H. A., Oyedele, L. O., & Olawale, O. A. (2020, August). Big data innovation and diffusion in projects teams: Towards a conflict prevention culture. *Developments in the Built Environment, 3*.

Rackham, N. (1998). *From Experience: Why Bad Things Happen to Good New Products.*

Rhein, F. (2021). *The Dynamics of Green Innovation in B2B Industries: A Systems Approach to Explain the Diffusion of Bioplastics.* Stuttgart: This Springer Gabler.

Rigby, E., & Garvin, M. (2012, August 23). Toward aligning academic and industry understanding of innovation in the construction industry. *International Journal of Construction Education and Research, 8*(4), pp. 243-259.

RISE. (2021). Retrieved April 2021, from https://www.ri.se/sv/om-rise/kvalitetssakring

Rogers, E. (2003). *Diffusion of Innovations.* New York: A Division of Simon & Schuster, Inc.

Schiederig, T., Tietze, F., & Herstatt, C. (2011). What is Green Innovation? – A quantitative literature review. (No 63 Working Papers).

Seaden, G., Doutriaux, M., & Nash, J. (2003, September). Strategic decisions and innovation in construction firms. *Construction Management and Economics, 21*, pp. 603-612.

SGBC. (2021). Retrieved 2021 April, from https://www.sgbc.se/

Slaughter, E. S. (1998). Models of Construction Innovation. *Journal of Construction Engineering and Management, 124*(3), pp. 226-231.

Stanwix, W., & Sparrow, A. (2014). *The Hempcrete Book: Designing and building with hemp-lime.* Cambridge: Green Books.

SundaHus. (2021). Retrieved April 2021, from https://www.sundahus.se/tjanster/miljodata/

Svanen. (2021). Retrieved April 2021, from https://www.svanen.se/en/about-us/

Sveriges Riksdag. (2004). *Sveriges Riksdag*. Retrieved 04 2021, from Sveriges Riksdag: https://www.riksdagen.se/sv/dokument-lagar/dokument/motion/industrihampa_GS02MJ254

Swedish Environmental Protection Agency. (2020). *About the Swedish Environmental Code*. Retrieved 04 2021, from Swedish Environmental Protection Agency: http://www.swedishepa.se/Guidance/Laws-and-regulations/The-Swedish-Environmental-Code/

Talke , K., & Heidenreich, S. (2013). How to Overcome Pro-Change Bias: Incorporating Passive and Active Innovation Resistance in Innovation Decision Models.

Tangkar, M., & Arditi, D. (2000, September). Innovation in the Construction Industry. *Journal of Civil Engineering Science and Application, 2*(2), pp. 96-103.

Toole, M. T. (1998, July 1). Uncertainty and Home Builders' Adoption of Technological Innovations. *Journal of Construction Engineering and Management, 124*(4).

United Nations Climate Change. (2021). Retrieved March 2021, from https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

United Nations Environment Programme. (2020). *2020 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.* Nairobi.

Walkley, B. (2020, August 27). *World Economic Forum*. Retrieved February 2021, from https://www.weforum.org/agenda/2020/08/sustainable-cement-carbon-emissions-sustainable-development/

Watts, J. (2019, November 25). Concrete: the most destructive material on Earth. *The Guardian*.

Wejnert, B. (2002). Integrating Models of Diffusion of Innovations: A Conceptual Framework.

Winch, G. M. (2003, September). How innovative is construction? Comparing aggregated data on construction innovation and other sectors – a case of apples and pears. *Construction Management and Economics, 21*(6), pp. 651-654.

Woolley, T. (2013). *Low Impact Building: Housing using Renewable Materials.* Chichester: John Wiley & Sons Ltd.

Xue, X., Zhang, R., Yang, R. J., & Dai, J. (2014, June). Innovation in Construction: A Critical Review and Future Research. *International Journal of Innovation Science, 6*(2), pp. 111-125.

Yin, R. (2018). *Case Study Research and Applications: Design and Methods.* Los Angeles: SAGE publications.

Yusof, N., Kamal, E. M., Kong-Seng , L., & Iranmanesh, M. (2014, September 25). Are Innovations Being Created or Adopted in the Construction Industry? Exploring Innovation in the Construction Industry. *Sage Open, 4*(3).

Zendehrouhkermani, F. (2020, August 28). *Statista*. Retrieved April 2021, from https://www.statista.com/forecasts/907333/construction-of-buildings-revenue-in-sweden

Appendix

Appendix A - Interview Questionnaire “Experts”

1. In the beginning, maybe you could tell us a little bit about your work.
2. How would you assess the innovativeness in the construction industry in Sweden?
3. What do you think are the main drivers of innovation in the construction industry? (What is the motivation?)
4. Where do new innovations come from? Where are they being developed? (Universities vs. Companies)
5. How would you assess sustainability and eco-friendliness in the construction industry in Sweden? How is the progress?
6. Where do you think hempcrete is standing in the Swedish market? (Unkown, known etc.)
    a. Are there any barriers?
7. Why are you a member of LMF30? Why do you think it is important to be active regarding climate action?
8. When it comes to the decision of what material will be used to construct a building, - the owner has the last word - who makes suggestions to the owner?
9. Any final comments?

Appendix B - Survey Questionnaire "Potential Adopters" and Results

"Attitude towards Innovation among People working within the Construction Industry"

This survey has the purpose to help us assess the subsequent interview. The answers collected from this survey will be used solely for the purpose of the Master's thesis research.

Thank you very much for participating!

PLEASE ANSWER THE QUESTIONS FROM THE PERSPECTIVE OF YOUR JOB POSITION IN THE COMPANY

1. Please give us your email address:

Definition of INNOVATIVE PRODUCTS in the context of the survey:
An improved version of an existing product or a completely new product that is not known in the market

2. A new innovative product appears on the market, what is your reaction?
   a. I want to give time and energy to be among the first to test the product
   b. I will rely on my intuition, but there has to be a need and I want to see the practical potential and benefits before I buy the product
   c. I would buy the product, but I need to see the advantages compared to current products and it has to be an established standard in the industry
   d. I would buy the product, because I have the fear of falling behind other competitors, but I hate risk
   e. Innovation means high risk and I will ignore the product in early stages

3. How much risk do you see in working with a new innovative product at your company? (Scale 1-5; 1 = very low, 5 = very high)
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

4. Which characteristics suit you the best (as your role within the company)?
    a. Visionary, imaginative and venturesome, willing to experience new ideas
    b. Strong sense of practicality, expect industry standards to have been established

5. How do you feel about technological change in the industry?
    a. I encourage and push change
    b. I welcome change
    c. I am comfortable with moderate change
    d. I tolerate change
    e. I try to ignore change

The following charts show the results of the conducted survey with a total of 16 participants. Three questions had the purpose to assess the participants. The second and the last question of the survey address the phases of the innovation diffusion process. Each of the five answers represents one of the five groups. Transferring that knowledge to the charts and combining the two questions, Figure 18 presents the results. The figures show that, according to the answer choices, the interviewees belong to the innovators, the early adopters or early majority group. Another question that was asked was directed at their personal characteristics referring to the two groups between the chasm: early market and mainstream market (see Figure 19). According to the previously discussed questions, none of the respondents belongs to the late majority nor to laggards. That is why even if half of the respondents picked the second answer which represents the mainstream market, it can be assumed that they are still part of the early market or the first group of the mainstream market (early majority).

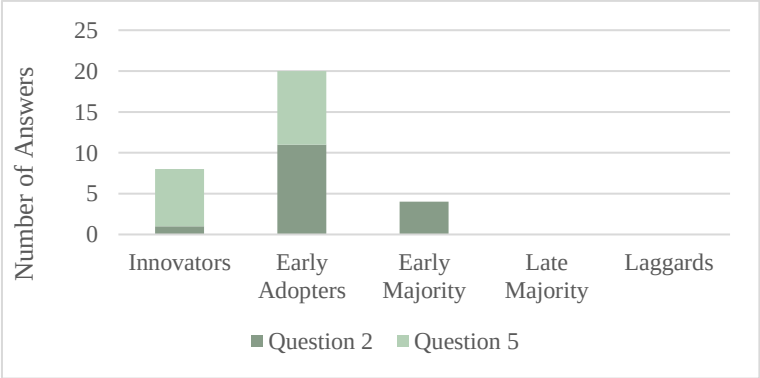

Figure 18: Interpretation of question 2 and 5

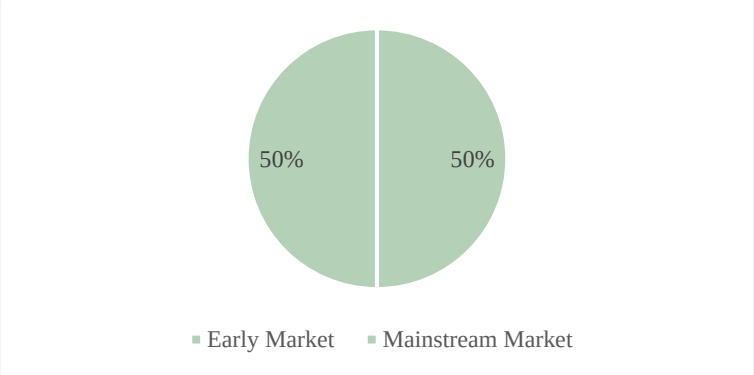

Figure 19: Interpretation of question 4

One important question of the survey addressed the risk attitude when working with a new innovative product at the company. The candidates could pick their risk level from a scale of 1 to 5, with 1 being the lowest risk and 5 the highest. As Figure 20 shows, almost half of the candidates see a rather high risk (level 4) regarding working with new innovative products. 37,5% picked a medium risk level and the rest chose a level of 2 out of 5 which indicates a rather low risk. All of that shows that risk plays a decisive role which is why further, and more detailed information was asked during the interview.

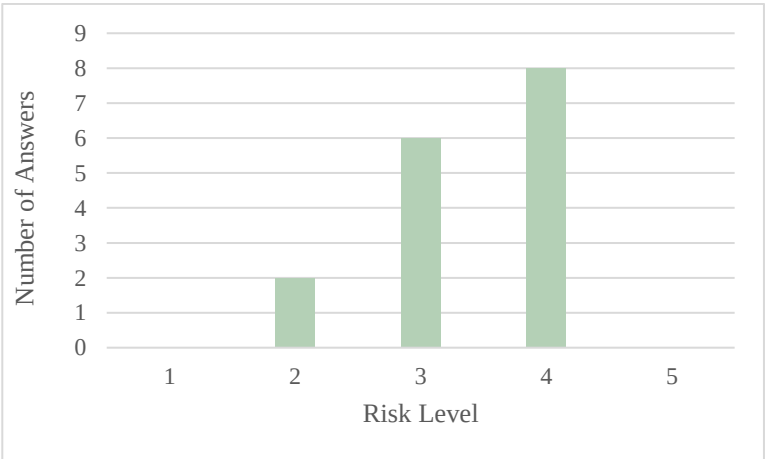

Figure 20: Answer results for question 3

Appendix C - Interview Questionnaire "Potential Adopters"

1. Maybe you can tell us a little bit about your work and role at company X?
2. What kind of clients are you mainly working with (private entities/individual vs. public) at company X?
3. Do you see a tendency of the clients/people wanting to build in a more sustainable way?
4. Referring to the survey:
    a. Regarding the risk you see when working with new innovative materials, you picked X out of 5, why?
    b. Optional individual question regarding survey
5. Where do you get the information about the fact that there is a new material on the market?
6. New material on the market:
    a. What are the features and factors that increase your interest?
    b. What can be the barriers?
    c. How do you evaluate a new material? (Based on what criteria)
        i. How about certifications?
    d. Do you test the new material before implementation? How?
    e. What requirements have to be met in order to implement it?
    f. You need to gain knowledge in order to work with the material (to do the calculations), would you be willing to invest time and if yes how much?
7. Have you heard about hempcrete?
    a. If yes, what do you think about it? If not, what is your first impression (regarding hemp)?
    b. When was that? How?
8. What do you think are the main drivers of innovation? What's the motivation to have a new innovation on the market?
    a. Role of LFM30?
    b. Why are you a member of LFM30? (if a member)
9. How would you assess the innovativeness in the construction industry in Sweden?

Appendix D - Additional Quotes

Positive Influences
"Making profit [...] developing sustainable solutions [...] basically, having the best, most attractive projects to put on the market is of course the driver. [...] There are also external forces that try to help us drive innovation. Let's say we want to produce a carbon neutral project and we haven't implemented any model for that. Then we will develop the carbon neutral model for this project and then we can evaluate it and implement it in our organisation as a whole. I think it's good when there are internal and external forces joining to drive innovation." - *Interviewee C2* *"If there is a regulation or a governmental decision about something, then they follow it. [...] I think that's a big driving force, the will of the municipality and the municipality has different political leadership"* - *Interviewee A3* *"Some companies are motivated by themselves. They want to have a green image and they want to go forward. And some do it just because the customers requires it. So they have to, they are forced. They also see the legislation that are coming and customers requirements, so they are forced. So I think that's due to those who really want and they want, they go in the lead, and those who, if they should stay in the business - they have to join it."* - *Interviewee RS* *"The Swedish regulations are very high, that is the problem. I think we are building houses that are too good and it takes a lot of materials and techniques that we do not even need, it is too much of everything. [...] We have to decrease the regulations to make sure the inventions get space."* - *Interviewee R2*
Negative Influences
"I have been a part of projects, like before I worked a lot with sports arenas, and so and there we were using materials that have never been used in Sweden and so needed some testing and so to be approved here. And it costs a bit extra [...] we know that it is harder than to choose something that everybody is familiar with, both when it comes to where to buy it and also how to consider like how to put it up, how to build it and so. Maybe the builders are not familiar with it and then we need to, you know, detail and study it, study how that is done and so. It is a little harder road, but it is definitely possible." - *Interviewee A3* *"I worked with a waterproofing company and they brought a new waterproofing product on market and it was much better. But it used the same amount of materials. I think it even needs*

less materials. But it was twice the price. And instead of just replacing their old product with this new better, more environmentally friendly product they tried to sell it for twice the price and then they tried to tell people that you had to use this new product cause the old product didn't perform which was not true." - *Interviewee E1*

"Some of my customers are always working with the same contractors and the same manufacturers [...] or they use some equivalent and then they do not really have an option to choose something else because it is decided in the company in the whole Sweden that they have to use this one because they have an agreement with this manufacturer [...] and then it is very hard to be able to use some innovative products. Because you know it is a tough decision for the organization, the customer to choose an innovative product for all their housing in all of Sweden. There is a very high amount of apartments and then the risk is higher if it does not work. And if you work with a smaller company, customer just works with one building in Malmö, nowhere else, then usually they do not have the energy or the economy to make innovative choice because it is a risk for them as well, even though it is not a lot work or a lot of apartments, it is still their only projects [...] But mostly it is because people don't really know what the new products are and they want to have confirmation or double confirmation or triple confirmation that it is as good as the ones they used to use." - *Interviewee CO2*

"We value our market position very highly and we are a very trusted brand so customers are kind of aware of what they are getting and we of course have to deliver this so it has to feel reasonably secure for us [...] We will never implement something that has a risk." - *Interviewee C2*

"In Sweden we basically have two different types of contracts. One [...] basically means that the client [...] contact the builder and basically say what they want. [...] And everything that's not specified, the builder gets to specify themselves. And the builder is responsible, delivering the complete building. And the other way to do it is that the client contacts the architects and the engineers and ventilation engineers, etc and have them do all the drawings and then you go to the builder and say 'here are the drawings, build this for me.' And then the client has decided everything, basically. [...] And what happens is that almost no one wants to do that, even though the latter option is the cheaper option also, normally, because the builder is obviously charging for the whole organisation of hiring the architect etc. But when you do all the drawings and you hired the builder to just build it, then you have a risk. [...] And if the construction industry were organised like it is in Denmark, or Great Britain, or Switzerland, or Germany or wherever, then the end client would have much more influence on how we are building." - *Interviewee A5*