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SUSTAINABLE ENTREPRENEURSHIP PROJECT

BARRIERS OF USING BIO-BASED MATERIALS BY CONSTRUCTION COMPANIES

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ABSTRACT

This research investigates the barriers to construction companies' adoption of bio-based materials, focusing on their potential to promote sustainability and support the circular economy approach. Through semi-structured interviews with representatives from three construction companies and secondary data, the study identifies critical barriers, including seven themes: technical, consumer, economic, governmental, supply chain, knowledge, and institutional. Despite their recognized benefits, the findings reveal a significant gap in secondary evidence regarding the practical application of bio-based materials in large-scale projects. The primary data collected from the interviews sheds light on this research gap by identifying the problems surrounding the wide-scale use of these materials, with consumer behaviours and barriers being a key theme. This research contributes to the existing literature by providing insights into the real-world obstacles practitioners face. It emphasizes the need for education, policy reform, and collaboration among stakeholders to facilitate the integration of bio-based materials. Recommendations for managers, educators, and policymakers are presented to enhance the adoption of sustainable practices in construction. The limitations of this study are also accounted for and there are certain recommendations that are provided that would circumvent these issues.

KEYWORDS

Bio-based Materials, Construction Industry, Construction Companies, Circular Economy, Sustainability, Barriers.

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1. Introduction

It has become increasingly clear that humans need to start considering protecting the Earth System and correspondingly the planetary boundaries that have been transgressed over the years (Galaz, et al., 2012). Planetary boundaries are a scientific framework designed to define the safe operating space for humanity within Earth's environmental systems. This concept identifies critical thresholds or limits for key environmental processes and systems that, if crossed, could lead to severe and potentially irreversible changes to the stability and resilience of Earth's systems (Steffen, et al., 2015). The topic of research, which is bio-based building materials will be mainly related to the planetary boundary of climate change, land system change and bio-sphere integrity, and how they can overcome the transgression of these boundaries.

1.1 Defining the Construction Industry

On a worldwide scale, a constant bane towards increased environmental damage and excessive use of resources stems from the construction industry. The construction industry encompasses all activities related to the planning, design, execution, and maintenance of buildings for varied purposes, infrastructure like roads, bridges and tunnels and other physical structures that are unrelated to the residential, commercial and industrial sectors. This industry is a significant sector of the economy and includes a wide range of services and professions involved in creating and maintaining the built environment (Sui Pheng, et al., 2019). The construction industry is made of up of many construction companies that can be described as business entities that specialize in building, renovating, and maintaining infrastructure, residential, commercial, and industrial projects. These companies can vary greatly in size and scope, ranging from small firms that focus on local residential projects to large multinational corporations that manage complex, large-scale infrastructure developments worldwide. They provide a range of services that range from designing and planning projects with the help of architects and engineers, overseeing and managing the construction projects and the renovation, and maintaining of existing structures. The types of projects vary from residential (construction of homes, apartment complexes, and housing developments) and commercial (construction of office buildings, shopping centres, hotels, and other business-related structures) to industrial (Construction of factories, warehouses, and plants) (Olanrewaju, et al., 2015). The main focus of the thesis will be on the residential and commercial sectors of the industry.

1.2 Environmental Impact of the Construction Industry

The industry, according to various studies, is following the traditional route of being risk averse and governed by short-term economic considerations, instead of long-term sustainability where all environmental factors are accounted for (Dams, et al., 2021). These environmental factors include excessive use of natural resources such as such as sand, gravel, timber, and metals (Satyam & Sharma, 2024). Extracting and processing these materials can lead to environmental degradation and depletion of non-renewable resources. Due to the excessive use of these natural resources, building projects generate significant amounts of waste, including demolition debris, packaging materials, and unused construction materials. Many of these materials end up in landfills, contributing to environmental pollution (Rose &

Stegemann, 2018). Overall, the construction industry is known as a 33% contributor towards greenhouse gas emissions and 40% of the global energy consumption (Sizirici, et al, 2021). The biggest contributor to this growing issue is caused by cement, which is the main component of concrete. The OPC ingredient used in making cement is responsible for 8% of the world's human carbon-dioxide emissions (Osial, et al., 2022). Poor planning and design can lead to material wastage, where excess materials are used or discarded, further exacerbating waste issues and moreover transgressing the planetary boundaries as discussed before. This traditional approach is leading to hurtful outflows, almost representing 30% of ozone depleting substances and 45% of the waste in the landfills as a direct result globally (Sharma, 2020). According to secondary data, these lack of sustainability stems from the reduced awareness and slow technological shifts towards greener solutions; that are usually seen as ineffective due to durability concerns and not monetarily viable because of the higher costs associated with acquiring sustainable materials (Hwang & Tan, 2012). Couple that with lack of standardized regulations surrounding sustainability, especially in the global south, and extremely complex supply chains; ushering the construction industry into a new era of sustainability has its challenges (Abidin, 2010).

The construction industry needs to go through a radical shift and change its course towards a more shared value approach where every stakeholder, both internal, that being the members of the industry and external, like the environment, need to be considered. Instead of only focusing on the economic outlook, the industry can start focusing on the triple bottom line, where the environment, society and financial aspects are all equally important (Kramer & Porter, 2011).

1.3 A Solution- Bio-Based Building Materials

A solution to this growing problem is answered through the use of bio-based materials that follows a circular economic perspective as compared to the traditional linear perspective (Dams, et al., 2021). Bio-based materials are substances derived from renewable biological sources, such as plants, animals, or microorganisms, as opposed to conventional materials that come from fossil fuels or other non-renewable resources (Blok, et al., 2019). These materials are produced through the extraction, processing, and conversion of biomass into usable products. They can include a wide range of materials, from biodegradable plastics and bio-composites to natural fibres and biopolymers (Jones & Brischke, 2017). The key characteristic of bio-based materials is that their primary feedstock originates from living organisms, which contributes to a reduction in the reliance on non-renewable resources and can potentially offer more sustainable alternatives in various applications (Jones & Brischke, 2017). Many bio-based materials have a lower carbon footprint, as the carbon dioxide absorbed during the growth of the biological sources can offset emissions produced during manufacturing (Blok, et al., 2019). They can offer diverse properties depending on their origin and processing, such as flexibility or strength, and are often designed to be compatible with existing manufacturing processes. However, their performance can vary, and they may be more expensive or less consistent than traditional materials (Ramdas, et al., 2021). While being made from plants and other recyclable materials they are mixed with binders in order to effectively emulate traditional building materials. They have started generating awareness in the construction sector and have characteristics such as low toxicity, minimal chemical emissions and the ability to be recycled (Hoang, et al., 2009). Despite several challenges,

ongoing research is continually enhancing their properties and expanding their applications, reinforcing their role in promoting environmental sustainability. Some examples of bio-based construction materials include bamboo, mycelium, hempcrete, bio-plastics, cork, straw bales and bio-based composites such as flax.

Even though there a myriad of reasons why bio-based materials are sustainable, they are rarely used in construction projects. This paper aims to research the use of bio-based materials by construction companies and conclude on a pertinent question, “What are the barriers of using bio-based materials by construction companies?”

2.0 Theory

In respect to the research question, the theory section of this research paper focuses on two key aspects and how the construction industry can move towards a more sustainable future. Firstly, the circular economy model, which stands as the primary concept being used in the paper. Secondly, previous knowledge encompassing the practical uses of bio-based materials in the industry, the barriers of doing so and how the industry has progressed towards circularity in the past with respect to bio based building materials. According to various academic sources, there is little evidence of bio-based materials being used in ongoing wide-scale construction projects around the world (Sparrevik, et al., 2021). There have been few large scale projects that have been documented to use bio-based predominantly but are known to be exceptions rather than the mainstream. Instead there are smaller scale pilot projects and localized initiatives that have made use of these materials (Maskell, et al., 2021). This rings true in developed economies such as Belgium, where bio-based materials have started generating interest, but yet again have not seen wide scale implementation on large scale projects of any nature (Salomone, et al., 2024). It is important to decipher why the stakeholders of this industry, while knowing the benefits of such materials are not recognizing their full potential and making these materials the norm and not a novelty. This stands as the major research gap that this paper hopes to investigate by understanding the barriers of using these materials in projects that construction companies undertake.

2.1 Introducing the Circular Economy Model

The circular economy model in the construction sector represents a transformative approach to building and infrastructure, aiming to reduce waste, maximize resource efficiency, and create a more sustainable and resilient built environment (Reike, et al., 2018). It is imperative for the construction industry to shift towards a circular economy model, as it focuses on restorative, regenerative intentionality and design (Geissdoerfer, et al., 2017). It functions on breaking the dominant logic of “take-make-consume and dispose” pattern of growth, while focusing on “decoupling” of resource use in order to foster economic growth (Reike, et al., 2018).

There are certain strategies that are being implemented in the industry that focus on circularity. Those include urban mining which is a process used to dismantle old buildings to recover metals, bricks and other materials for reuse in new construction projects, rather than sourcing new materials every time. The process of Building Information Modelling (BIM) is also a new phenomenon where the life cycle of materials are simulated in order to identify

opportunities for recycling and reuse (Azhgaliyeva & Rahut, 2022). Closed loop water systems are also being used where water from sinks and showers is treated and is used for flushing and irrigation. There also systems in place such as solar roofs that are used to generate renewable energy and LED lighting systems that are highly energy-efficient, consuming significantly less electricity than traditional incandescent or fluorescent bulbs (Rameshwar, et al, 2020). This reduces the overall energy demand of buildings, contributing to a lower environmental impact. Bio-based materials are also mentioned in literature but suffer from reduced exposure and are generally not well researched enough to be implemented in all kinds of building projects (Sparrevik, et al., 2021).

2.2 Problems in Implementing Circularity in the Construction Sector

According to Hossain, et al., (2020), there are a myriad of barriers in implementing circularity in the construction sector. Barriers can be defined as resistances that causes individuals or entities to limit their actions. These can be stimulated due to overarching internal factors such as conservative institutional setups and external factors such as government policies that affect the situation greatly (Chrispim, Mattsson & Ulvenblad, 2024). This includes policy issues. They can be described as a lack of standardized guidelines and regulatory frameworks for circular construction that can hinder the adoption of circular practices. There is a global need for policies that incentivize the use of recycled materials and support the development of circular supply chains (Philp, 2015). The construction industry is also traditionally slow to adopt new practices, and there may be resistance to the changes required for a circular economy. This includes the need for new skills, technologies, and business models and a focus on collaborative actions between various stakeholders (Heidari, et al., 2019). Therefore, this paper aims to examine bio based building materials and what barriers afflict them which stifles the circularity economy initiative in the construction industry.

2.3 Current State of Bio-Based Material Implementation

Le, et al., (2023) did a comprehensive analysis of existing literature surrounding bio-based building materials and found that there is a limited scope of knowledge and awareness surrounding wide scale use of these materials in large construction projects, moreover hindering the implementation of the circular economy model, which is required to usher in an era of sustainability. Although it is important to point out that these materials have been tested in small scale and experimental projects. After doing an assessment-methods analysis, it was deciphered that most of the publications focus on environmental analysis of these materials (Le, et al., 2023). Numerous studies have conducted life cycle assessments to compare the environmental impacts of bio-based and conventional materials such as concrete, steel and plastics. Results generally indicate that bio-based materials have a lower environmental footprint, particularly in terms of greenhouse gas emissions and non-renewable energy consumption (Galimshina, et al., 2022). Bio-based materials, especially those derived from plants, have the unique ability to sequester carbon dioxide from the atmosphere during their growth. This makes them carbon-negative or carbon-neutral over their lifecycle (Galimshina, et al., 2022). However, the overall sustainability of bio-based materials also depends on factors such as land use, resource availability, and end-of-life disposal. There is little heed to the economic and social aspects of using them. For example, there is miniscule information about how expensive or how economical these materials are

in application (Krasny, et al., 2017). Moreover, publications are not deciphering the governmental barriers such as the lack of certification processes in using these materials (Vanhamaki, et al., 2019). Technical challenges are also being overlooked, such as moisture sensitivity, biodegradation, and limited fire resistance, which require further research and innovation to enhance the performance of bio-based materials (Pawelzik, et al., 2013). As seen above, there is limited data on all kinds of barriers that deter companies in using them in their ongoing projects. Henceforth, it is imperative to answer the research question and understand the barriers to help in further research of these materials.

3.0 Methods

3.1 Research Design

The research design for this paper consists of mainly using primary data and secondary data to get to the crux of the matter, which was to decipher the barriers that cause construction companies to not use bio based materials more frequently. As pointed out in the introduction as well as the theory section, the drivers of using these materials are pretty clear, that is, supporting the circular economy model and to protect our planetary boundaries from more harm, which is why the research is predominantly focused on the barriers.

Firstly, existing secondary data on bio-based materials was scrutinized, primarily focusing on the research gap. There is little academic literature on bio-based materials being used in large construction projects all around the world (Sparrevik, et al., 2021). While there have been several small scale projects that have used bio-based materials as their foundation, they do not prove that these materials can be a viable solution to emulate traditional building materials such as concrete. It has become increasingly clear that there is little emphasis the lack of data surrounding the advantages and disadvantages of using these materials on a large scale (Salomone, et al., 2024).

Henceforth, semi-structured interviews were undertaken that focused on getting answers from construction companies regarding the research question. In accordance to the interviews, certain findings were established which have been analysed and discussed further in the upcoming sections. The research ends with certain recommendations for practical use as well as further research. It also outlines how this particular research had certain limitations of scope as well as a data pool which is insufficient.

3.2 Data Collection

Primary Data

The selection criteria for this research is based on participants that work in companies that make use of bio-based materials in their construction projects (Kallio, et al., 2016). It was imperative that they held a certain position in the company where they worked with these materials closely in order to provide better data. Since the research was primarily based in the Netherlands and there are a vast array of circular construction companies that work here, three companies were chosen from said country to participate in the research. They will be now known as Company A, Company B and Company C, so as to anonymise the participants

and their company's name. This was done in accordance to the ethical standards that were prescribed by the university as explained in section 3.4. In order to approach these participants, help was taken from an organization called *Circular Friesland*, that readily collaborate with companies that have circularity at the heart of their mission, values and goals (Circular Friesland, n.d). These companies were thoroughly researched before being approached, by looking into their websites as well as their ongoing projects. It was imperative to know that their goals aligned with the research being done in order for the findings to be conclusive.

The primary data collection was undertaken on the basis of semi-structured interviews (Magaldi & Berler, 2020). In order to decipher the barriers of using bio-based materials by construction companies, an interview guide was developed (Adams, 2015) after thoroughly researching the companies in question. Certain interview guide structures were studied in order to formulate questions (Naz, et al., 2022.) that would lead to an open ended conversation, rather than following a strict script that would not interest the participants. This interview guide (Appendix A) comprised of detailed questions about circularity in the construction industry and how bio-based materials can be a possible solution. In the beginning, participants were asked general questions about their construction company, their various projects and what their particular role was in these projects. Once it was ascertained that the participant had significant knowledge about the building projects, they were asked about their views on bio based building materials and how their company uses these materials in their own projects. According to the answers they were providing, the questions delved into figuring out which barriers play a significant role in limiting the use of bio based materials in their projects. They were also compartmentalized into various sections and themes which will be further described in the findings and discussion section of the research. Moreover, the participants were also questioned on the lack of awareness of these materials in the construction industry and if these materials are a viable solution to emulate traditional building materials. The interviews usually ended with an open ended question about how circularity is important and how these bio based materials are indeed pushing the industry towards a closed loop and a greater focus on the triple bottom line which are the social, environmental and economic aspects.

Once the interview guide (Appendix A) was developed, the companies were contacted through email and were asked to take part in the research. They were provided with an information sheet which described the research and an informed consent form (Appendices B and C). This was to be signed by the various participants in order to receive the proper consent from them as they were being recorded. The interviews took place on the online platform called Google Meet and were recorded in order to transcribe the data. The interviews averaged thirty-five minutes, which yielded valuable insights into the obstacles faced by these companies in adopting bio-based materials.

Secondary Data

Secondary data was first scrutinized to figure out the research gap for this paper. It has been detailed in the introduction and the theory sections of this paper. In order to make up for small data pool that was used to collect primary data, certain reports, interviews and social media posts were examined from the companies mentioned above. Even though the primary

data provided a wealth of information on the topic, it was not enough for a comprehensive outlook on answering the research question. Since the academic literature on bio-based materials has been mentioned as sorely lacking, it was interesting to scrutinize the practical information which was provided by these companies on their various websites. All of this data was found on public domains and does not violate the code of ethics that has been applied to this paper. The secondary data that was used was also appropriately anonymised.

3.3 Data Analysis

Once the primary data was recorded from the participants in Company A,B and C, it was transcribed and coded using the Atlas.ti software (Campbell, et al., 2013). During the coding process, thematic patterns and themes were established in order to formulate the barriers. These barriers were identified and segregated through the process of first and second order codes. Quotes were analysed from the transcripts and segregated based on metrics such as environmental, institutional, economic, monetary and social factors. The first order codes used inductive reasoning while the second order codes that were developed use deductive reasoning. All the codes that were used to formulate the themes will be displayed in the findings section of the research paper in Section 4.4.

3.4 Ethical Standards

The research was done in accordance to the ethical standards that were prescribed by the university. This included providing a research checklist to the university which involved answering general questions about the topic and mode of data collection, in order to ascertain that the research was ethical and did not cause harm to any of the participants. The participants themselves were given an information sheet (Appendix C) that detailed the mode of data collection as well as the aim of the research. They were given a general idea of what questions to expect and how the data collection process would carry on. It was also imperative for them to sign the informed consent sheet (Appendix B) which was provided by the university. It described how their data will be anonymised by placing capital letters instead of their company names. Apart from that, they also consented to come on an online platform called Google Meet for the interview and to be recorded so as to form an initial transcript of the data collected to further scrutinise, analyse, code and, moreover, answer the research question.

3.5 Limitations of the Research Design

The main limitation of the research design stems from the lack of participants that were willing to take part in this research. Unfortunately, the data collection process began in the month of July, where most of the chosen participants were on holiday. Due to these unforeseen circumstances data collection was limited to three participants who were willing to take part in research on a short notice. It took place in the beginning of August and the data was needed to be submitted in 3 weeks' time. In order to make up for the lack of primary data, secondary data from these companies was further scrutinized where reports, social media posts and other interviews were analysed in order to formulate the barriers of bio-based materials.

The participant selection process was also limited to one country but could have benefited with a more muti-faceted approach of comparing the barriers faced by companies of two or more countries. It would have been interesting to see how the barriers would differ based on geographical location, culture and economic conditions.

4.0 Findings

4.1 Introduction to the Interviews

This study focused on evaluating the barriers associated with the implementation of bio-based materials in the construction sector, with particular attention to their integration within circular economy concept. The research sample comprised three companies, each engaged in construction projects that involve varying degrees of bio-based material usage. Despite the recognized potential of these materials in advancing circular construction, their widespread adoption has been limited by a range of barriers, as highlighted by the interview participants.

The interviews commenced with a brief introduction of each company, ensuring that they met the criteria for inclusion in this research. The companies selected were diverse in their involvement in construction projects, with two—Company B and Company C—being directly engaged in residential and commercial projects. In contrast, Company A operates as a consultancy and third-party contractor for various types of projects, including industrial ones. This diversity in the nature of projects undertaken by these companies provided a comprehensive perspective on the use of bio-based materials across different sectors of the construction industry.

Following the introduction, the participants were asked to describe their roles within their respective companies. To ensure a holistic approach to the research, the representatives selected for the interviews held distinct positions within their organizations, allowing for a multifaceted understanding of the challenges associated with bio-based materials. The representative from Company A, for instance, is a project manager with detailed knowledge of the technical and logistical aspects of construction projects. This individual's insights would provide useful data in understanding the specific barriers encountered in the implementation of bio-based materials. The representative from Company B, who is the co-founder and CEO, provided an overview of the institutional and financial hurdles that arise in the course of project development. This perspective was crucial in identifying the broader organizational challenges that influence decision-making processes. Finally, the representative from Company C, an innovation manager, offered insights into the strategies employed to introduce and integrate new materials and technologies aimed at enhancing project sustainability, while also describing barriers surrounding the lack of knowledge about these materials.

4.2 Understanding of Bio-Based Definition

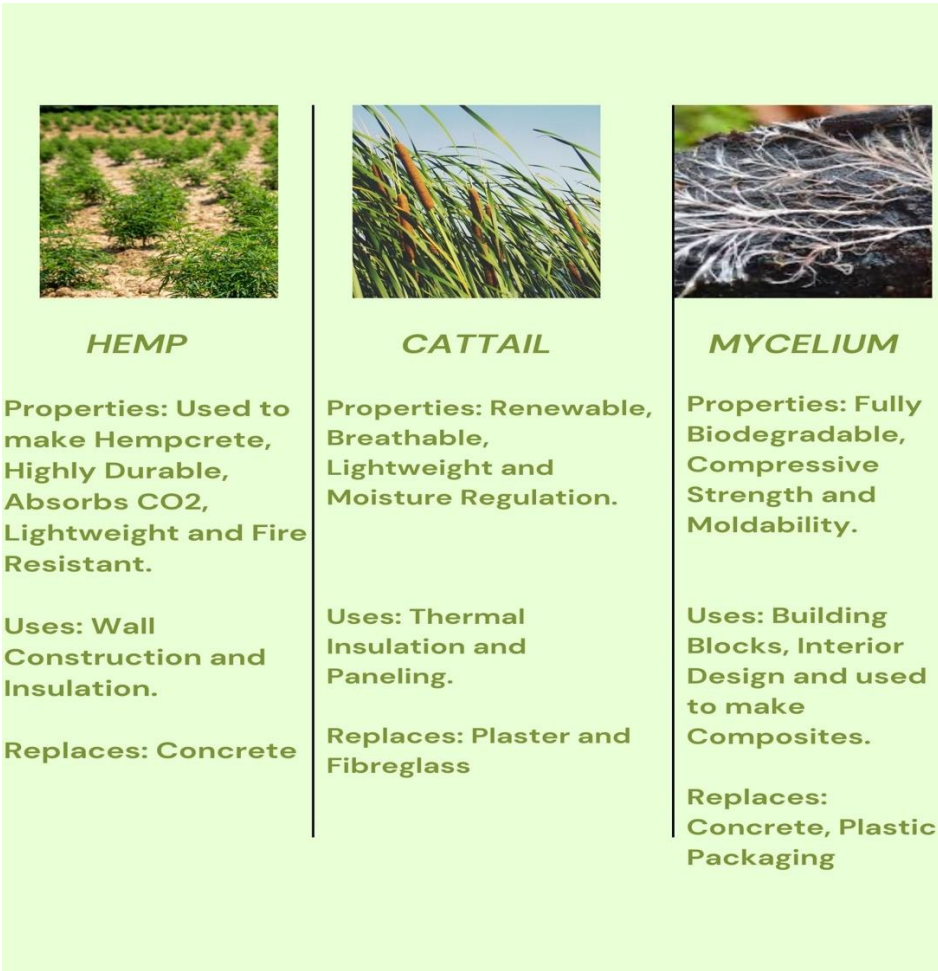
The second question posed during the interviews focused on the definition of bio-based materials. Interestingly, none of the participants could provide a precise definition, instead listed various materials they associated with the term. The inability to clearly define bio-based

materials suggests that there is still considerable ambiguity in the industry about what constitutes bio-based materials, which may be a contributing factor to their limited use. This observation underscores the need for more comprehensive education and dissemination of information regarding bio-based materials within the construction sector. This is clearly seen as the participant from Company A stated, “Our company has consulted on projects where bio-based materials are involved. I am not an engineer, so I am not able to define it as such but we have seen projects being made with recycled products and these materials”. The same can be said for the participant from Company C who stated, “The definition is something that changes a lot according to newer types of materials that are introduced. So, I cannot give you a precise one”.

4.3 Application of Bio-Based Materials by Participating Companies

The third question addressed the participants' experiences in utilizing bio-based materials in their projects. Here, the responses varied significantly between the companies. Representatives from Company A and Company C provided examples of how they had incorporated bio-based materials into their projects, although they noted that the use of such materials was still relatively limited.

These are three examples of bio-based materials that the participants mentioned, their properties and how they can replace their conventional counterparts. Secondary data from their social media posts and websites were also used in creating this Figure.



Despite the limitations in the use of bio-based materials, all participants expressed a strong interest in increasing their use in future projects. This desire reflects a growing recognition of the potential benefits of bio-based materials, particularly in the context of circular economy principles. However, the participants also highlighted significant barriers that currently hinder the widespread adoption of these materials. These barriers were explored in greater detail through the fourth, fifth, and sixth questions, which were pivotal in the research as they directly addressed the challenges faced by the companies in using bio-based materials, the perceived significance of these challenges, and the viability of bio-based materials as substitutes for traditional construction materials.

4.4 Coding Process

The responses to these questions revealed a high degree of commonality in the challenges identified by the participants. This commonality facilitated the development of seven key themes that encapsulate the barriers to the adoption of bio-based materials. These themes were derived through a process of coding the interview responses, with particular attention paid to recurring issues mentioned by all three participants. The identified barriers include technical challenges, cost-related concerns, regulatory hurdles, supply chain limitations, lack of knowledge and expertise, resistance to change within the industry, and uncertainties regarding the long-term performance of bio-based materials. Each of these barriers represents a significant impediment to the broader adoption of bio-based materials, and their cumulative effect has resulted in the continued reliance on traditional materials in the construction sector.

First order and second order codes were generated from the transcripts and were used to identify themes. They are stated in the Figure below. The second order codes will also be highlighted in bold in the upcoming sections.

First-Order Codes	Second-Order Codes	Themes Generated
• New to consumers and developers. • Less knowledge about the positive aspects of bio-based materials.	• Lack of Awareness • Low Demand	Consumer Barriers
• Established supply routes for conventional materials. • Low supply of bio-based materials. • Difficult to transport from far-away places.	• Limited Availability • Transportation and Logistical Problems	Supply Chain Barriers
• Lack of governmental interest in bio-based materials. • Restrictive practices by the Government	• Lack of Building Codes and Regulation • Lack of Standardized Certification	Governmental Barriers
• Examples in data that prove there is a	• Lack of Durability • Level of Distrust	Technical Barriers

durability problem with some of these materials.		
• Bio-based materials are new to the market and have not been properly discussed in the mainstream.	• Limited Research and Development • Lack of Expertise	Knowledge Barriers
• Low supply that causes premiums on bio-based materials. • Nascent market and still used in niche projects.	• Higher Costs • Economic Uncertainty	Economic Barriers
• Companies tend to stick to tried and tested conventional materials. • High amount of capital invested, making the industry more wary of new materials if they fail.	• Risk Aversion • Conservative Approach	Institutional Barriers

4.5 Theme 1: Consumer Barriers

The most significant barrier in the eyes of the participants is that the demand for bio-based materials in the construction industry is still relatively low, partly due to a **lack of awareness** among consumers and developers about the benefits of these materials. The participant from Company B stated, “Ya, its new to a lot of people so sometimes clients are not in favor of it. It comes down to tried and tested materials against something that is extremely new to them and the industry. When we tell them about the applications, they need proof. We tell them about our own projects but it can be a hard sell sometimes”. This low demand can discourage construction companies from investing in bio-based solutions, as they may perceive a limited market for such materials. The participant from Company A described how their clients are usually looking for other types of greener solutions because they are unsure about bio-based materials. They stated, “Many people do not know about these materials and it is difficult for people to wrap their head around it. I mean companies approach us to make their buildings greener but they expect things like solar paneling, insulated roofs and something more general. This market is new and people do not know the advantages of using these materials”.

Bio-based insulation materials, such as wood fibre or cork, offer environmental benefits over conventional insulation materials like mineral wool or polyurethane foam. This was also looked into in one of the reports by Company C, where they stated that cork is viewed as a niche product and is discarded in favour of unsustainable synthetic materials. Consumer awareness of these benefits is limited, leading to **lower demand**. Moreover, developers prioritize cost and performance over sustainability, opting for conventional materials that are more familiar and widely accepted.

4.6 Theme 2: Supply Chain Barriers

The availability of bio-based materials is another significant barrier which was discovered. Unlike conventional materials, which benefit from well-established global supply chains, bio-based materials are often produced on a smaller scale. This **limited availability** can lead to challenges in sourcing sufficient quantities of materials, particularly for large-scale projects. The use of straw bales as an insulation material has been explored as a sustainable alternative to mineral wool by Company C. The participant described the problem by saying, "We use mineral wool (conventional building material) and straw in our projects and there was this shortage of high quality straw bales that caused delays in construction and made us look for last minute alternatives". The same can be said for mycelium based products as pointed out in the website of Company C. These products are still in their testing and developmental phases and there are limited facilities that supply these materials on a commercial scale in the Netherlands. This limited availability could also have other ramification such as increased costs, making straw bales and mycelium based products less attractive to developers and clients.

The **transportation and logistics** of bio-based materials can also pose challenges. Many bio-based materials are bulky or perishable, making them difficult to transport over long distances without incurring significant costs or risks of degradation. Bamboo, a rapidly renewable bio-based material, was considered for use by Company C due to its strength and sustainability. The participant described the issue by stating "We also tried using bamboo for our one of smaller projects and that was a big fiasco. The logistics was messed up. It is a strong product but is grown far away in tropical locations. There is always a risk of degradation. And the costs were massive and the carbon footprint did not help the deal. We went for a different option altogether, because of all of these factors." Moreover, due to the perishable nature of these materials, it becomes increasingly difficult for companies to reliantly use these materials.

4.7 Theme 3: Governmental Barriers

Building codes and regulations in the Netherlands are often designed with conventional materials in mind, making it difficult for bio-based materials to meet the necessary standards. This was described in a quote from the participant form Company B. They said, "There is definitely a problem there because building codes are pretty ambiguous about bio-based materials. Yes, there are subsidies that accelerate the use of the materials but there needs to be some form of standardization". These regulatory challenges have slowed the adoption of bio-based materials, as construction companies have to navigate complex approval processes to ensure compliance with safety, structural, and fire resistance standards.

The lack of standardized certification systems for bio-based materials presents another barrier. While conventional materials have well-established certification processes that provide assurance of quality and performance, bio-based materials often lack such standardized assessments as understood from the participants. This absence of certification can make it difficult for construction companies to confidently choose bio-based materials, particularly for large or high-profile projects. The participant from Company B talked about how in the Netherlands, the NEN (Netherlands Standardization Institute) provides

certifications for many construction materials. Some examples were shared in an interview with an executive from Company C include NEN-EN 206 (ensures that concrete used in construction meets performance criteria and NEN-EN 1090 (relates to the execution of steel and aluminium used in construction and if they comply with EU standards) (Netherlands Standardization Institute, n.d). On the flip side, the NEN-EN 16785 provides certification for bio-based content in materials (Netherlands Standardization Institute, n.d). However, bio-based materials like bio-based polymers or mycelium-based products may not yet fall under these standardized certifications, creating uncertainty for construction companies. According to secondary data, Without recognized certifications, these materials may be perceived as riskier, limiting their adoption.

4.8 Theme 4: Technical Barriers

There is a common perception that bio-based materials are **less durable** or less capable of withstanding harsh environmental conditions compared to conventional materials. This perception is particularly prevalent in the construction industry, where long-term performance and reliability are paramount. The participants do believe that there is a certain **level of distrust** in the industry with regards to the durability of these materials. The participant from Company C described, “Timber is so widely used but is always susceptible to fire, rot and insects. Some of shipments did get ruined. The durability of these materials gets questioned a lot due to all of this. Not to mention the excessive premiums we have to pay”. Despite advancements in timber treatments and fire-resistant designs, these concerns can limit the use of timber in the Netherlands, particularly in multi-story buildings or infrastructure projects.

The maintenance requirements of bio-based materials are also critical factors that influence their adoption. Construction companies may be hesitant to use materials that require more frequent maintenance or have uncertain long-term performance, as this can increase costs and complicate building management. A great example was provided in secondary data that described how linen (flax) insulation must be kept dry to prevent mold growth. These buildings also require proper ventilation and moisture retentive systems in place for the linen (flax) insulation to work.

4.9 Theme 5: Knowledge Barriers

The adoption of bio-based materials is also hindered by a **lack of expertise** and knowledge among architects, engineers, and builders. This was also clear in the interview with the participant from Company B. Many professionals in the construction industry are more familiar with conventional materials and may lack the skills or experience needed to design and build with bio-based alternatives. This knowledge gap can lead to resistance or reluctance to experiment with new materials. The participant in Company B described this issue by stating, “Everyone in our company did not have much of an idea about these materials and it took a lot of time for my team to get acquainted with these materials. It was new to me for sure and still new to some of my new hires”. It was also proven through secondary data that bio-based materials such as polylactic acid have lower thermal resistance and require knowledge on the part of builders to execute properly in piping and fixtures.

While there is growing interest in bio-based materials, the participants also commented on the research and development efforts needed to optimize these materials for construction. They are still in their early stages. **Limited research and development** can result in a lack of reliable data on the performance, durability, and environmental impact of bio-based materials, making it difficult for construction companies to make informed decisions. This became clearer when the participant from Company C stated, “There is not enough research done into these materials. That is for sure. Because of this it is difficult to bring ideas to designers in our company because they ask for technical and structural viability which is not studied enough in my opinion. Then the ideas get eventually shut down and replaced by unsustainable materials.” When it was asked if bio-based materials can substitute traditional building materials, the participant from Company B stated, “Right now it is tough to say. There needs to be more research and these materials can work well in conjunction with many of the traditional materials. But there is a future. My company believes in a future where some of these materials will be the norm”.

4.10 Theme 6: Economic Barriers

One of the most significant barriers, as discussed in the interviews, in the adoption of bio-based materials in the Netherlands are the **higher initial costs** associated with these materials. Bio-based materials, such as timber, hemp, and straw, often come with a price premium compared to conventional materials like concrete, steel, and synthetic insulation. This cost difference is primarily due to the smaller scale of production, less developed supply chains, and the novelty of the materials in the construction market. “There is this problem of price definitely. Everyone has the bottom line of making a profit while doing something good for the environment. But it does take more money to use these products definitely” was a direct quote from the participant in Company A. An appropriate example was given in one of the interviews that described the Cross Laminated Timber. It is a bio-based material that has gained attention for its structural capabilities and sustainability. However, the cost of CLT was significantly higher than that of traditional concrete and steel for Company A, making it less attractive for developers who are focused on minimizing upfront costs. In the Netherlands, this cost disparity has limited the use of CLT to niche projects or those with strong sustainability mandates. The participant from Company B also mentioned, “Well, many clients and sometimes my carpentry team are not able to deal with the costs. New materials, novel in nature, low supply. This causes a hike in price for sure”.

As described in the previous sections, the construction industry is inherently risk-averse, and the **economic uncertainty** surrounding bio-based materials further exacerbates this. The market for bio-based materials is still developing, leading to fluctuations in prices and availability. The participants described how certain construction companies as well as theirs are sometimes reluctant to commit to these materials due to concerns about future cost stability and supply chain reliability. The participant from Company A described how Hempcrete, a bio-based alternative to traditional concrete, is not yet produced on a large scale in the Netherlands. The participant said, “When companies buy concrete also, they buy it in bulk while something like hempcrete cannot be bought in that fashion. There is an inherent supply problem with hempcrete.” The limited number of suppliers and the nascent market make the pricing of hempcrete volatile. Construction companies may hesitate to use

hempcrete in large projects due to the uncertainty surrounding its cost and availability, preferring instead to stick with more predictable and stable materials like conventional concrete.

4.11 Theme 7: Institutional Barriers

The construction industry is known for its **conservative approach** to new materials and technologies. This **risk aversion** is driven by the high stakes involved in construction, where mistakes can lead to significant financial losses, safety issues, and legal liabilities. As a result, construction companies may be hesitant to adopt bio-based materials, which are perceived as less tested or proven than conventional options as described by the participants.

Resistance to change is another barrier that affects the adoption of bio-based materials. The construction industry is characterized by established practices and long-standing relationships with suppliers of conventional materials. Changing these practices and relationships requires a significant shift in mindset, which can be challenging to achieve. Conventional materials such as concrete have been the dominant construction material for decades, with a well-established supply chain and industry expertise. Transitioning to bio-based alternatives, such as bio-concrete or rammed earth as described in secondary data reports, requires not only technical adjustments but also a cultural shift within construction companies as described by the participants. This resistance to change can slow the adoption of bio-based materials, even when the environmental benefits are clear.

5.0 Discussion

This research has provided valuable data into the barriers that construction companies face when attempting to implement bio-based materials into their projects. The findings indicate that while there is a growing recognition of the potential benefits of bio-based materials in promoting sustainability and supporting the circular economy, significant obstacles remain. These barriers, as described in the earlier section include **technical barriers, consumer barriers, economic barriers, governmental barriers, supply chain barriers, knowledge barriers and institutional barriers**. The study describes the need for a multifaceted approach to overcome these challenges and facilitate the use of bio-based materials in the construction industry by construction companies.

From the interviews conducted with representatives from three construction companies, it was deciphered that the perception of bio-based materials is often clouded by lack of data regarding their performance and reliability compared to traditional materials. There was difficulty in articulating a clear definition of bio-based materials reflects a broader issue identified in the literature—a lack of technical knowledge and data regarding these materials. Moreover, the representative from Company B demonstrated a lack of clarity regarding the specific ways in which bio-based materials were utilized in their projects. This discrepancy can be attributed to the different roles and levels of technical knowledge among the participants. As the CEO of the company, the representative from Company B might not be as intimately involved in the technical aspects of material selection and application as the other participants. This lack of detailed knowledge on the part of senior management could be indicative of a broader trend within the industry, where decision-makers may not fully grasp

the potential and application of bio-based materials due to insufficient awareness or understanding.

Participants and secondary data expressed concerns about the technical limitations of bio-based materials, such as moisture sensitivity, lack of durability and thermal resistance, which hinder their widespread adoption. Additionally, the lack of standardized building codes and regulations that accommodate bio-based materials poses a significant barrier. The research also highlights the importance of education and awareness-raising initiatives to inform stakeholders about the benefits and potential applications of bio-based materials. The supply chain for these materials was also put into question due to nascent markets for these materials. Whereas traditional materials have established global supply chains. This in turn also affected the financial viability of using these materials as they have higher initial costs of adoption.

5.1 Value and Contribution of this Research

The value of this research lies in its contribution to the existing body of knowledge regarding bio-based materials in the construction sector and circular economy practices that the construction sector can undertake. By identifying and analysing the barriers to adoption, this study fills a critical gap in the literature, as mentioned in the theory section of this paper. The theory section described how there is little evidence on why these materials are used in large scale projects (Le, et al., 2023). The practical challenges regarding these materials faced by construction companies is often overlooked in academic literature and is moreover discussed in the findings section of this paper. Furthermore, the research provides a foundation for future studies aimed at exploring solutions to these barriers, thereby advancing the discourse on sustainable construction practices.

This research aligns with previous studies that have identified the potential of bio-based materials to contribute to sustainability in the construction industry. While existing literature has emphasized the theoretical benefits of bio-based materials, this study provides a more integrated understanding of the real-world challenges that practitioners encounter as seen by the primary data gathered in the interviews and the secondary data that was analysed from the participating companies. The findings suggest that while the drivers for using bio-based materials are clear, the barriers are equally pronounced and require attention in order to push the industry towards the circular economy model.

The primary contribution of this research is its identification of specific barriers to the adoption of bio-based materials in the construction industry. By providing insights from industry practitioners, the study offers a practical perspective that complements existing theoretical frameworks. Additionally, the research contributes to the literature on the circular economy model by emphasizing the role of bio-based materials in promoting sustainable construction practices as there was limited data and how there is need for research and development in order for companies to adopt these materials more frequently. The findings can inform policymakers, industry leaders, and educators about the challenges and opportunities associated with bio-based materials, ultimately fostering a more sustainable construction sector.

5.2 Recommendations for Further Research

Based on the outcomes of this research, several recommendations can be introduced for practitioners in the construction industry:

1. **For Management**: Construction managers should prioritize training and education for their teams regarding the benefits and applications of bio-based materials. By fostering a culture of innovation and sustainability, companies can better position themselves to use these materials in their projects.

2. **For Education**: Educational institutions should incorporate bio-based materials into their curriculum, ensuring that future construction professionals are equipped with the knowledge and skills necessary to implement sustainable practices. This could include hands-on workshops, case studies, and partnerships with industry stakeholders.

3. **For Policy**: Policymakers should work towards developing and implementing building codes and regulations that support the use of bio-based materials. Although some of these are in place in the Netherlands, it is important to provide a better emphasis on the matter. This could involve creating incentives for companies that adopt sustainable practices, as well as funding research initiatives aimed at improving the performance of bio-based materials.

5.3 Limitations of the Research

While this research was designed to address the barriers to the use of bio-based materials in the construction industry by construction companies, several limitations must be acknowledged. Firstly, the sample size was relatively small, consisting of only three companies. This in turn was due to time constraints and willingness of individuals that wanted to participate in this research. This limits the generalizability of the findings and may not fully represent the diverse perspectives within the industry. It was also based on the construction industry of one country in Europe that is known for its sustainability initiatives. If the data set were to include countries from the global south for example, the barriers may differ substantially. Although the research relied on semi-structured interviews, which provided rich qualitative data, it may have been subject to biases based on the participants' experiences and perceptions.

Furthermore, the study focused primarily on the barriers without exploring potential solutions and drivers in depth. This was also due to time constraints and a lack of a data set to carry on further investigations. Future research could benefit from a more comprehensive examination of successful case studies where bio-based materials have been effectively integrated into construction projects.

Based on the limitations of this research, several avenues for future research are suggested:

1. **Longitudinal Studies**: Conducting longitudinal studies that track the adoption of bio-based materials over time could provide a look into the factors that influence their

integration into construction practices. This could help identify trends and best practices that emerge as the industry evolves.

2. **Comparative Studies**: Future research could explore comparative studies between companies that have successfully adopted bio-based materials and those that have not. This could be used on the specific strategies and practices that facilitate successful implementation.

3. **Technical Innovations**: Investigating the development of new technologies and innovations that enhance the performance of bio-based materials could provide critical insights into overcoming the technical barriers identified in this research. Collaborations between academia and industry could be particularly important in this regard.

4. **Policy Impact Studies**: Research examining the impact of policy changes on the adoption of bio-based materials in construction could provide valuable information for policymakers. Understanding how regulatory frameworks influence industry practices can help shape more effective policies that promote sustainability.

5. **Awareness and Education Initiatives**: Future studies could evaluate the effectiveness of awareness and education initiatives aimed at promoting bio-based materials in the construction industry. Assessing the impact of these initiatives on stakeholder perceptions and behaviours could inform the development of more targeted outreach efforts.

6.0 Conclusion

In conclusion, the interviews conducted with representatives from the three companies and secondary data gathered provide a deeper look into the current state of bio-based material implementation in the construction sector. While there is clear enthusiasm for the potential of these materials, significant barriers remain that must be overcome to achieve widespread implementation. The research highlights the need for greater education, awareness and dissemination of information regarding bio-based materials, as well as the importance of addressing the technical, economic, governmental, institutional and supply chain barriers that currently limit their use. Moreover this answers the research question of this paper, which states ""What are the barriers of using bio-based materials by construction companies?" As the construction industry continues to evolve towards more sustainable practices in the Netherlands, the findings of this paper suggest that bio-based materials have a crucial role to play in the transition to a circular economy. However, realizing this potential will require concerted efforts from all stakeholders involved in the construction process.

In the discussion section, it was proven that there is a certain ambiguity when it comes to the definition of bio-based materials. This was seen in all interviews and was pronounced in the interview with Company B. The section went on to relate the findings of this paper to the theory of circular economy and provide data that was lacking in academic literature on the topic. Certain recommendations were also developed for future research in this field. It lay

emphasis on training of individuals to better implement these materials in their projects to foster sustainability, provide better education on these materials by universities and for policies to shift towards the support of bio-based materials.

The discussion section also highlights the limitations of this study, mainly being the lack of primary data that was gathered by construction companies. More data would have been helpful in formulating the barriers as there was a certain commonality in the answers given by the participants. Henceforth, the findings could have included a more diverse perspective and less generalised data. Secondary data was used to supplement this lack of primary data as well. The scope of this study was also put into question as it is only focused on the Netherlands. In order to circumvent these issues, recommendations for future research on this topic were given. This includes longitudinal and comparative studies that would require research take place over a longer period and compare construction companies. Technical innovations and policy impact studies can also provide better data on how these materials are progressing and being adopted. Moreover, the effectiveness of awareness and educational initiatives would also provide data on the impact they are having on the stakeholders of the industry.

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Appendix A

Interview Guide

1. Describe your construction company and the projects that they undertake while describing your role in it.

2. How would you define bio-based building materials? (If they do not have a clear answer, provide a general idea and give examples of the materials as well as ongoing projects.)

3. How does your company use bio-based materials into their construction projects? If no, are there any plans of using bio-based materials? (Discuss the concept of circularity with them and how it is integral to change the industry)

4. What are the main issues/barriers you face while substituting traditional building materials with these new bio-based materials? (After the barriers are discussed, try to compartmentalize them and get their views.)

5. Considering the barriers that we have discussed, which ones do you feel are the most important?

6. Do you consider bio-based materials to be a viable substitute to traditional building materials? Please elaborate. (Discuss the barriers in conjunction with this question.)

7. Do you think bio-based materials have any benefit in transitioning towards a circular economy? Could you please explain? (End with getting their thoughts on the research and how worthwhile it is.)

Appendix B

INFORMED CONSENT FORM

Title study: What are the barriers of using bio-based materials by construction companies?

Name participant: Participants A, B, C

Assessment

- I have read the information sheet and was able to ask any additional question to the researcher.

- I understand I may ask questions about the study at any time.

- I understand I have the right to withdraw from the study before the 15th of July without giving a reason.

- I understand that at any time I can refuse to answer any question without any consequences.

- I understand that I will not benefit directly from participating in this research.

Confidentiality and Data Use

- I understand that none of my individual information will be disclosed to anyone outside the study team and my name will not be published.

- I understand that the information provided will be used only for this research and publications directly related to this research project.

- I understand that data (consent forms, recordings, interview transcripts) will be retained on the Y-drive of the University of Groningen server for 5 years, in correspondence with the university GDPR legislation.

Future involvement

- I wish to receive a copy of the scientific output of the project: yes/no

- I consent to be re-contacted for participating in future studies: yes/no

Having read and understood all the above, I agree to participate in the research study: yes / no

Date

Signature

To be filled in by the researcher

- I declare that I have thoroughly informed the research participant about the research study and answered any remaining questions to the best of my knowledge.

- I agree that this person participates in the research study.

Date

Signature

Appendix C

INFORMATION SHEET

TITLE OF THE STUDY: What are the barriers of using bio-based materials by construction companies?

Dear participant,

Thank you for your interest in participating in this research. This letter explains what the research entails and how the research will be conducted. Please take time to read the following information carefully. If any information is not clear, kindly ask questions using the contact details of the researchers provided at the end of this letter.

WHAT THIS STUDY IS ABOUT?

- This study aims to research the barriers of using bio-based materials in construction projects, specifically residential projects. These will be ascertained through semi-structured interviews, involving a maximum of 10 questions and a cap of 1 hour with 5-7 participants from construction companies based in the Netherlands.

- Since construction companies in the Netherlands have adopted the use of bio-based materials, it will be easier to gauge the barriers of using these materials. If the research were to include companies that are not sustainable, it would defeat the purpose of the research.

WHAT DOES PARTICIPATION INVOLVE?

- By taking part in this research, you will be asked questions based around the adoption of bio-based materials in construction projects that your company is undertaking and what the perceived barriers are in using them. The interviews should last about 30 to 45 minutes and will be following a detailed interview guide.

DO YOU HAVE TO PARTICIPATE?

- Participation in this research is not mandatory and will be done voluntarily by the participants involved.

- You reserve the right to withdraw from the study before I start the process of data analysis which will start by 10th August, as there is no formal contract between the researcher and the participants. You can choose not to answer a question if there is a problem in doing so.

ARE THERE ANY RISKS IN PARTICIPATING?

- There are no prescribed risks in participating in the research. The company names and participant names will be anonymised according to the ethical standards of the university. The data from the interviews will be stored in a safe location with minimum risk of leakage. It will be deleted once the research is complete.

ARE THERE ANY BENEFITS IN PARTICIPATING?

- While there may be no direct benefit of this research to your company, it will contribute to little known academic data on the application of bio-based materials in construction projects as well as circularity in the construction sector as a concept.

HOW WILL INFORMATION YOU PROVIDE BE RECORDED, STORED AND PROTECTED?

- The company names and participant names will be anonymised by using letters instead of names. The research will be conducted according to the ethical procedures of the ethics committee in Campus Fryslan and through the platform Google Meet.

- Only I, the researcher and my supervisor will have access to the data and it will be safely stored in my computer on the RUG google drive.

- The data will be deleted once the research is complete.

WHAT WILL HAPPEN TO THE RESULTS OF THE STUDY?

- The end goal of the research is to ascertain the barriers of using bio-based materials by construction companies with the help of primary data provided by you. It will contribute to academic literature that is sorely lacking in this field, and also propagating the idea of circularity in the construction sector. The thesis will also be available in the university library.

ETHICAL APPROVAL

- This research study has been approved by the ethics committee in Campus Fryslan.

- I pledge to uphold myself to the ethical standards that I have mentioned.

INFORMED CONSENT FORM

- I have also provided an informed consent form for you to sign, which describes your intention to participate and your option to withdraw, if you choose to do so.

WHO SHOULD YOU CONTACT FOR FURTHER INFORMATION?

Name: Anuvrat Agarwal
Email: a.agarwal.8@student.rug.nl
Phone: +919903000909/ +31630300708

Appendix D

Link to Google Drive Transcripts:
https://drive.google.com/drive/folders/1a1MdawQKnDyevRRZ1S7wchFoQs_ZSWtD?usp=share_link