The potential of bamboo in woodworking practices in Germany

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Abstract

This thesis was written as part of the Masters Programme in Sustainability Science and Policy at Maastricht University, the Netherlands. It addresses the difficulties of sustainable tropical wood and wood product supply with the long growth rate of timber and weak regulatory frameworks being a key barrier for its sustainable extraction. To meet the current demand for tropical timber, bamboo could be used as an alternative. Bamboo grows quickly and can be used for similar product production such as flooring and furniture.

To process bamboo in Europe, wood manufacturers need to have similar knowledge for the processing of bamboo as for the processing of timber. Since timber is dominating European markets, bamboo products should meet existing timber user and producer demands. Hence, the objective of the thesis was to analyze the potential of bamboo in German woodworking practices.

The thesis made use of Social Practice Theory (SPT), which puts practices at the center of the analysis. These are defined by interconnected elements; material, competences and meaning. To understand embedded practices, timber and bamboo manufacturers were interviewed. Desk research provided a solid background on bamboo and timber practices. Forty interviews were conducted with timber users at IKEA to understand their demands on timber products and their interests in the purchasing of bamboo products. Follow-up interviews were conducted with timber producers to understand their knowledge and experiences around bamboo.

The thesis illustrates that practices between bamboo and timber differ with contrasts in the mechanical properties of timber and bamboo. It is illustrated that there are similarities between the skills needed to process bamboo and timber. This only applies to bamboo boards. These are similar to timber boards and can be processed almost equally by German manufacturers. Key limitations to the enhanced use of bamboo boards are; limited design choices which differ to timber boards that have various designs. Due to the different designs, different feelings are associated with the materials. To create similar feelings, bamboo boards should be diversified.

In conclusion, bamboo currently seems to remain a niche product and a useful option next to other wood products in Germany. Lastly, the study recommends to diversify the type of bamboo boards available for woodworkers to introduce bamboo further into the German market. It also recommends to include bamboo as a renewable resource which could help to meet the targets of the EU Energy Directive. Under this directive, timber is used as renewable energy. Due to bamboo’s quick growth and high starch content, it could be suitable as biomass instead of timber. Key limitations of the study were limited time to interview more manufacturers and to apply SPT in-depth for both resources.
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CHAPTER ONE

INTRODUCTION, PROBLEM STATEMENT & THEORETICAL FRAMEWORK
1. Introduction and problem statement

In the light of sustainable development, a key challenge remains in current consumption and production patterns that put the carrying capacity of our planet at risk (Arrow et al., 1995). Current economic models and trade agreements seem less oriented towards sustainable development (Rees, 1992). Instead, they seem to stimulate uneconomic growth in which environmental and social costs outweigh production benefits (Daly, 1999).

Natural resources are being exploited to keep up with the current product demand of the Global North (Rice, 2007). A consequence of the unsustainable extraction of natural resources such as timber is the environmental burden that it leaves behind, such as forest loss (Rice, 2007). Forest loss is associated with a decrease in biodiversity (Li, Aide, Ma, Liu & Cao, 2006) and land degradation (Foley et al., 2007). It is also associated with a loss in ecosystem services and livelihoods (Morse et al., 2009). Livelihoods are affected by those who make a living from the production and the sales of forest resources (Morse et al., 2009), but also those who depend on forest resources for their livelihoods (Pokharel & Nurse, 2004).

Forest product production and consumption thereby affect the three pillars of sustainability which according to the Brundtland Report (as cited in Drexhage & Murphy, 2010) compromise the economy, society and the environment. Ideally, those three pillars should be balanced; Forest products should be produced to the extent that livelihoods are secured, that ecosystems are preserved and that economic outputs are aligned. However, this scenario is ideal and currently does not take place. A challenge for sustainable timber product production is, for instance, timbers’ long growth rate which varies between 25-50 years before it can be harvested (Brienen and Zuidema, 2007; Shearman et al., 2012).

To combat deforestation, alternative resources for timber should be promoted in timber processing countries. These should have similar features as timber and grow quicker than timber to be adapted by the market. Such a resource could be bamboo which matures already within three to five years and has been used for timber like applications such as flooring. However, since the mechanical characteristics differ between bamboo and timber, it is questionable to what extent manufacturing practices of timber are similar to those of bamboo and to what extent bamboo can be adapted in processing countries such as Germany.

To evaluate the latter, the thesis begins with a literature review. The literature review provides an understanding of the reasons and efforts taken to combat the unsustainable extraction of timber.
It follows with an identification of the current drivers of timber product demand but also its embeddedness in the timber processing country; Germany. Since bamboo is suggested as an alternative resource to timber, the next part of the literature review compares both resources.

In the last part, the theoretical framework is explained. Social Practice Theory is used to explain, how elements of practices interact with each other; meaning, competences and material (Shove et al., 2012). The elements are applied to the bamboo and woodworking sector to analyze elements of both industries in Germany. The overall aim of the study is then to understand the potential of bamboo for its further introduction into German wood manufacturing practices.

The “methodology” section explains how data was collected and analyzed. Data consists mainly of interviews. These were conducted with timber and bamboo product producers as well as users. In addition, desk research was used and later compared to the interviews. The result section then follows and begins with the outcomes of the desk research and interviews. With this, each element (meaning, material and competences) is illustrated per resource and methodology. In the end, these are related to each other. In the last part of the result section, the outcomes of the consumer interviews are described.

The thesis ends with a discussion which compares the elements of timber and bamboo per sub-question. A conclusion section than answers the main research question by pointing out the potential for bamboo in wood manufacturing practices. A recommendation section for policy and society follows. The last part of the study lists the limitations.
1.2 Literature Review

The following chapter illustrates the consequences of tropical timber demand. It also illustrates different efforts taken to combat deforestation, while critically reflecting on these. The literature further illustrates the complexity of tropical timber trade with reasons being different types of demand for timber and timber products. Overall there is a growing demand for timber products in Europe such as Germany, but the demand seems to increase due to the embeddedness of timber and timber products in European markets. Therefore, the literature review continues to provide an example of timber embeddedness in Germany.

Since the aim of the study is to understand the potential of bamboo in woodworking practices, the following part of the literature review visualizes key features and barriers of bamboo utilization. In the last part of the literature review, bamboo is compared to timber. This section then follows with the theoretical framework, which is used to compare bamboo with timber practices in Germany.

1.2.1 The Backbone of tropical timber demand

Increasing timber demand contributes to environmental degradation through the depletion of tropical forests and their ecosystems (Siry, Cubbage and Ahmed, 2005; Shearman, Bryan and Laurance, 2012; Obidzinski, Dermawan, Andrianto, Komarudin and Hernawan, 2014). Although the extraction of tropical timber, if managed sustainable, could encourage sustainable development in tropical countries, the current extraction rates (Shearman et al., 2012), missing regulations and a lack of forest-related policy initiatives as well as lacking compliance serve as a barrier for the protection and sustainable management of forests (Levin, 2008; Siry, 2005). As oppose, illegal or unsustainable logging operations are enhanced through increased demand for forest products (Center for Promotion of Imports [CBI], 2016; Hahn und Knoke, 2013) which according to Sohngen and Sedjo (2000) is estimated to grow by one percent annually.

To keep up with this demand, large areas of primary tropical forests are often completely logged which leads to the destruction of unique tree species that are not used for commercial purposes (Shearman et al., 2012). According to Shearman et al., (2012) among commercial tree species, most favored are those with smaller growth cycles between 30-

| Each year, some 140,000 sq km of rainforests are destroyed. Rainforests are being felled for timber by logging companies and cleared by people for farming. The most endangered rainforests are those in West Africa, where human populations are doubling every 20 years, and in Central America and South-East Asia (Worldwildlife Fund for Nature, 2019, para. 5) |
35 years. However, the majority of tropical tree species have longer growth cycles, which range between 45 to 500 years and are less used for commercial purposes (Shearman et al., 2012).

Although there are efforts taken to ensure the sustainable and legal extraction of tropical timber such as with Reduced Impact Logging (RIL) (Hosonuma et al., 2012) or timber legality verification systems (Obidzinski et al., 2014), a key challenge remains in forest product demands which continues to support unsustainable and illegal (Buckrell and Hoare, 2011; Obidzinski et al., 2012) logging practices. Practices such as RIL are less likely adopted because they reduce short-term profits of logging operations “by permitting fewer trees to be harvested per hectare to cover the fixed costs of roads and other infrastructure” (Putz, Sist, Fredericksen and Dykstra, 2008, p.1340), or they require that cutting cycles of trees are extended (Putz et al., 2008) which serves as an economic disincentive.

The latter is also highlighted by Fox, Keenan, Brack, and Saulei (2011) and Yosi, Keenan and Fox (2011). The authors illustrate that although sustainable forest management practices in Papua New Guinea resulted in regenerative capacities of forest areas (Fox et al., 2011; Yosi et al., 2011) it was less likely encouraged by loggers. While cutting cycles should average 35 years, these were halved by loggers to create shorter returns in profit. In some cases, the land was immediately converted to agricultural land or other plantations (Katsigris et al., 2004).

To combat these logging practices, the European Union (EU) set up Voluntary Partnership Agreements (VPAs) (Obidzinski et al., 2014) to promote legal trade of timber between producer and consumer countries. VPAs are agreements between the EU and timber-producing countries (Katsigris et al., 2004). These should guarantee that timber exported to the EU originates from legal sources (Oliver, 2015).

VPAs are also facing a barrier in their efficiency (Obidzinski et al., 204). The authors highlight that in order for Indonesian exporters to comply with the VPA, various enterprises need to be certified under the Indonesian Timber Certification System (SVLK). This process is difficult since it requires a high cost and currently, only a small share of enterprises can bear the cost for certification. Likewise, the pressure to become certified further stimulates local corruption (Obidzinski et al., 2014).

Because of the difficult certification processes, fewer timber exports into the EU of countries that signed VPAs, have been observed (ITTO, 2018; Rupert, 2015). Among six VPA implementing countries “a total of 98 000 m3 of plywood was supplied to the EU in 2013, down from 482 000 m3 in 2004 (Rupert, 2015, p. 43). While the reduction of timber export into the EU sounds promising, it also entails a reverse effect. Stricter regulations lead to more timber being exported to
countries with weaker import regulations. This concept is referred to as trade diversion, meaning that countries like China with weaker timber import regulations are more likely importing uncertified timber. These are then processed and exported to countries with stricter import regulations (Jianbang, Cerutti, Masiero, Pettenella, Andighetto, and Dawson, 2016).

The latter could be misleading to consumers who are concerned about the sustainability and legality of their products. For instance, under the current VPA regulations, flooring consumers are shifting “away from tropical suppliers in favor of products from China and non-EU temperate countries,” (Rupert, 2015, p. 11). However, purchasing products from countries with weaker tropical import regulation does not necessarily proof that the wood used for product production originates from legal or sustainable sources (Jianbang et al., 2016).

1.2.2 Drivers for tropical timber import

Demand and market embeddedness for timber and timber products serve as an important driver. In terms of tropical timber, there is an annual increase in the demand for tropical products such as for plywood and fiberboards followed moldings, joinery and veneers in European countries (International Tropical Timber Association [ITTO], 2018). The lowest demand exists for tropical timber products such as flooring and timber logs with their import varying between 300 thousand metric tons of flooring and 25 thousand metric tons of timber log imports between 2017 and 2018 (ITTO, 2018).

While there seems to be a shift in consumer preferences with more consumers wanting non-tropical timber products or at least certified timber products (Centre for the Promotion of Imports [CBI], 2016; Brockmann, Hemmelskamp & Hohmeyer, 1996) there seems to be no particular differences in terms of the amount of product types demanded and supplied between 1996 and 2018. Brockmann et al., (1996) illustrate a demand for tropical timber products such as furniture, flooring and plywood with those products being equally high demanded today (ITTO, 2018).

The high demand for tropical timber products is characterized by its’ unique characteristics. Tropical timber is more resistant to negative influences than domestic timber, it has various material characteristics, it has the ability to remain unchanged for long durations, it has various forms of colors, it is very stable, and has various unique grains (Brockmann et al., 1996).

Secondly, the high demand could be reasoned with the fact that due to weaker regulations in the Global South (Levin, 2008; Siry, 2005), timber products are more steadily available for export. This promotes the utilization of sustainably managed timber in the EU but further encourages import of tropical timber and tropical timber goods to meet the existing EU demand for wood and wood products. With this argument, there seems to be no difference between tropical and non-
tropical timber features. Study findings from Kroth, Kollert, Flippi (1991) (as cited in Brockmann et al., 1996, p. 67) concluded that there are no major differences in the use and processing of tropical and non-tropical timber species by wood manufacturers.

Besides, there also seems to be a regulatory push towards the need for more timber. This is encouraged by EU regulations that aim at promoting greener development. The EU Energy Directive aims at a 20% target of energy consumption from renewables by 2020 (Lehner, 2013; O’Brien and Bringezu, 2017) and a 32% by 2030 (European Commission [EC], 2019). Under the Directive, the use of domestic renewable energy is heavily promoted with wood and wood products such as briquettes and pellets accounting to a total of 45% of total EU renewable energy consumption (EC, 2019).

Although the Directive aims at a sustainable future by shifting away from the use of coal and fossil fuels for the provision of energy, it also provides a new challenge for the timber industry in which long growth rates and the sustainable management of forests in the EU such as Germany lead to a shortage of timber supply (Lehner, 2013). This shortage affects both the energy industry as well as the timber production industry (Lehner, 2013).

Hence, tropical timbers characteristics, the need for more renewable resources and continues supply, challenge the sustainable extraction of timber in both domestic and foreign markets (see Figure 1: Summary, Tropical timber Demand and Causes).

Figure 1: Reasons for the tropical timber demand
Because of the high demand for timber, new resources, products, or technologies for wood processing and its supply must be found (Lehner, 2013). This seems challenging because of the embeddedness of timber in markets that are adjusted to domestic and tropical timber production and consumption such as in Germany.

1.2.3 Timber embeddedness in the German market
The embeddedness of timber in German markets dates long back. In 1921, the author Michalski listed that more than 29 million cubic meters of wood were produced with more than 15 million cubic meter of wood being imported in Germany annually. Most of the wood, which was available in great variety and thickness, was used for the production of various products; the piano, barrels and pulp.

Michalski (1921) argued that because Germany had low paying wages, various timber products were produced there. “Nowhere could the woodworking businesses get the material they needed for their particular purposes faster and cheaper, as we know in Germany” (Michalski, 1921, p. 2). Timber continues to be established well in the German market, but “the import of timber has shifted over the years. The import structure has shifted away from round wood, sawn-wood and moldings towards processed products such as plywood and building material” (Brockmann et al., 1996, p. 47).

According to the economic association for the German Wood Trade (Der Wirtschaftsverband für den Deutschen Holzfachhandel) (2019), the role of timber trade and production also expanded over the last years. It is more diversified and involves various actors in retail, wholesale and manufacturing. These actors are engaged in the entire timber supply chain, which involves the acquisition of timber resources, processing and sales (Der Wirtschaftsverband für den Deutschen Holzfachhandel, 2019).

Due to the diversification of the entire timber industry, the target group of timber diversified as well. It includes woodworkers, the construction industry and end-users. Since timber is demanded in greater variety, it is mostly traded in the form of semi-finished products such as lumber, wooden doors, parquet, or wood boards. Because of this greater demand for material diversification, customers play a central role. "More than ever, traders are challenged to deliver the right product to the right place at the right time" (Economic Association for the German Wood Trade, 2019, para. 1)

While timber has a long history in Germany and seems deeply embedded, it is difficult to focus on the German market as an isolated system. German timber is also sold in international markets, which include markets in and outside of Europe (ITTO, 2002). Germany is also importing
international wood for product production. These products are then sold on the German market but also international markets. Likewise, Germany is also importing semi-finished products which are processed and either sold on German or international markets (Goh et al., 2013).

Because it is difficult to track the origin of a product, it is difficult to oversee the sustainable usage and production of timber products with the long growth rate of timber being a barrier for its sustainable and quick extraction. Therefore, it is important to identify new resources (Lehner, 2013) that could supplement timber or possibly serve as an alternative in European markets such as the German market. These should fulfill existing demand criteria for timber.

1.2.4 Bamboo as a timber alternative

A possible alternative to timber is bamboo, which fully matures between three to five years (Nath, Das & Das, 2004). This growth rate is relatively low in comparison to timber, which usually reaches its full growth between 25-50 years (Brienen and Zuidema, 2007; Shearman et al., 2012). Although a tropical grass, bamboo has timber like properties and can be used for the production of diverse timber like products (Diver, 2006) such as panels, flooring, furniture, paper and fiberboard (Hunter, 2003; Buckingham, Wu and Lou, 2014) but also plywood (Wang, Peng, Chai, Peng, Min and He, 2006) and moldings (Mathew, 2002). Since these products that are imported from the tropics (ITTO, 2018), bamboo could serve as a potential and more sustainable substitute.

While literature highlights the large timber like usage of bamboo in the tropics (Diver, 2006; Mekuriaw, Urge & Animut, 2011; Buckingham et al., 2014), there is little scientific literature available on the usage of bamboo in the Global North such as in European markets. A reason for that could be its ecological characterization as “gras” which makes its trade to Europe difficult where existing trade schemes are set up for conventional timber under the so-called Harmonized System (HS) codes (Buckingham et al., 2014). Under the existing HS scheme, bamboo can be traded in limitations to Europe such as in the form of finalized products; bamboo flooring, plywood, paper articles, seats and furniture (Buckingham et al., 2014).

Likewise, there is limited scientific literature regarding the interest or demands of European timber manufacturers or consumers for bamboo. Since the EU is a large importer of tropical timber and timber products (ITTO, 2018), it is important to explore from a sustainable resource perspective whether bamboo could become an integrated part in the existing European markets. Since tropical timber and timber products are largely exported from China, Indonesia, Brazil, Malaysia and Cameroon (CBI, 2016) where bamboo is also growing and processed (Lobovikov
et al., 2007) it is crucial to understand how applicable the use of bamboo could be for European producers as well as consumers.

Although bamboo could serve as an alternative to timber, the embeddedness of timber in the European markets in which “wood product manufacturing is the largest subsector in terms of its number of enterprises and number of persons employed,” (European Commission, 2011, p.36) could bear a challenge for its integration. This large sector and timbers’ natural occurrence in Europe may also provide an indicator for its embeddedness, applications and uses. This suggests that the application of a new resource such as bamboo could be more difficult to integrate.

In addition, there are fundamental differences between bamboo and timber. Bamboo has no cambium, which is a structural key characteristic of timber (Schwab und Schlusen, 1999). At the same time, there are similarities between bamboo and timber such as that both consist of cellulos, hemicellulos and lignin which are according to Schwab and Schlusen (1999) is favorable for wood products such as flooring.

Besides technical aspects, there are also aspects such as structure and color (Schwab and Schlusen, 1999). In comparison to timber, bamboo has various nodes that divide different sections of the bamboo. Those are visible in flooring as opposed to timber flooring which has no nodes. In addition, bamboo flooring is a rather light-colored material which leads to different color patterns during sunlight exposure (Schwab and Schlusen, 1999).

Also, bamboo is commonly known as an Asian resource and German consumers could perceive bamboo as a foreign material. Van der Lugt and Otten (2006) highlight that European consumers associated it with a Panda, or Asian style and less likely to a high-end product such as flooring and strengths.

Although similar products can be produced from bamboo, manufacturing practices likely vary due to the different characteristics of both resources. Since bamboo could serve a potential alternative resource it is important to understand manufacturing practices of timber and bamboo in the European markets. These practices are crucial to identify in order to understand whether bamboo manufacturing practices could be similar to the practices of timber product manufacturers and if bamboo could, therefore, be further introduced.
1.3. Theoretical Framework

Social Practice Theory (SPT) was used to understand the potential of bamboo in German timber manufacturing practices. It was applied because it puts practices at the center of the analysis (Shove, Pantzar and Watson, 2012). Through practices that are followed by multiple entities, specific trends such as the manufacturing practices of bamboo and timber can be analyzed.

While SPT puts practices at the center of the analysis, other theories such as Multi-Level Perspective (MLP) and Technological Innovation System (TIS) could also be used. According to Geels (2005), MLP is used to illustrate how transition occurs through the interaction of specific processes in three different levels; niche, socio-technical regime and socio-technical landscape. The niche level consists of multiple innovations or new processes from which the regime is protected. The socio-technical regime consists of multiple actors, institutions and technologies that maintain and stabilize the current system. Unlike niches, regimes are rather constant and do not change frequently. The Landscape-level rarely changes as it is established by demographics, politics, infrastructure, and other structures that are difficult to change (Geels, 2005).

According to Suurs and Hekkert (2009), TIS is used to explain the nature of a technological change by focusing on seven functions. If all of these are fulfilled, an innovation is likely to succeed. These seven functions consist of; “1. Entrepreneurial activities, 2. Knowledge development, 3. Knowledge diffusion, 4. Guidance of the search, 5. Market formation, 6. Resource mobilization, and 7. Support form advocacy coalitionists “ (Suurs and Hekkert, 2009, p. 672).

While MLP and TIS require intensive research into multiple actors and institutional set-ups, SPT focuses on practices and avoids distinguishing “levels” such as with the MLP. In comparison to TIS, SPT puts ways of working more central than “technology” as such. Due to the time limitations of the study as well as the interest in manufacturing practices, SPT seemed more applicable than MLP or TIS.

Practices of SPT contain elements that are embedded into our culture and consist of meaning, competences and materials (see Figure 2: Social Practice Theory et al., 2012). According to Shove et al. (2012), the element material looks at objectives, tools and the infrastructure that underlie a particular practice. Meanings have a cultural perspective, with socially shared expectations and conventions towards the usage of practice but also symbolic meanings, aspirations and ideas (Jüttner,
Competences refer to the required knowledge and skills that are necessary for the execution of a specific practice (Shove et al., 2012).

Although practices are made up of different elements, practices can vary as they are never fixed or singular (Higginson, McKenna, Hargreaves, Chilvers and Thomson, 2015). Practices “represent a pattern which can be filled out by a multitude of single and often unique actions reproducing the practice (a certain way of consuming goods can be filled out by plenty of actual acts of consumption)” (Reckwitz, 2002, p. 250).

The advantage of using practice theory is that multiple patterns can be observed and diagrammed (see Figure 3: Practices diagrammed). These can present an overall image in which certain elements regarding a practice may be more or less dominant than others (Higginson et al., 2015). In Figure 3, different colors (white to dark grey) are allocated to different elements. Elements in the center are more dominant than those on the outside. Therefore, SPT can help to create an insight into the dominance, differences and similarities of certain elements of practicing industries. It can also aid in illustrating the salience of certain element characteristics per industry.

The study applied SPT to understand what type of producer practices underlie current product manufacturing systems. Within the meaning domain, the study analyzed concepts and ideas of manufacturers to engage in bamboo or timber production. The competence element aimed at analyzing the needed knowledge or skills to process timber and bamboo. Lastly, the material element was used to understand various bamboo and timber characteristics that play a role in their utilization. This distinction derives from Latour (1993) who perceives that things such as air and bacteria are an integral part of materials as these are equally shared and available between practicing groups and therefore, become an essential part of practices.

To further delineate between these elements, the element material focused on different characteristics that are defined by industrial producers as necessary for the adaptation and use of

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1 Since the study aims at understanding timber as well as bamboo practices, it is narrowed to products in manufacturing systems throughout the entire TRP in the domain of; panels, flooring, furniture, and fiberboard (Divers, 2006; Buckingham et al., 2016)
a particular tree species in the supply chain (Brockmann et al., 1996). Brockmann et al., (1996) highlight the importance of material quality such as growth structure, transportation, recovery rates, and grains for timber resources. Since material also considers "the stuff of which products are made" (Shove et al., 2012, p.14), the theory was also used to examine materials and their characteristics.

Competences were divided into skills and know-how in the production chain. According to Walker (2017) and Gielis (2002), particular knowledge for the treatment, processing and preservation of bamboo (Gielis, 2002) and timber (Walker, 2017) is needed.

In terms of meaning, there is little scientific comparison. Therefore, the meaning element evaluated the different concepts, norms and values (Shove et al., 2012) of manufacturers in production. Table 1 (Elements and Description associated with Manufacturing Practices) summarizes the elements and their characteristics that were analyzed in the study.

<table>
<thead>
<tr>
<th>Material</th>
<th>Competences</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Growth structure</td>
<td>• Know-How</td>
<td>• Ideas</td>
</tr>
<tr>
<td>• Recovery Rates</td>
<td>• Skills</td>
<td>• Norms</td>
</tr>
<tr>
<td>• Transportation</td>
<td>• Treatment</td>
<td>• Values</td>
</tr>
<tr>
<td>• Grain</td>
<td>• Processing</td>
<td>• Concepts</td>
</tr>
<tr>
<td>• Mechanical Characteristics</td>
<td>• Preservation</td>
<td></td>
</tr>
</tbody>
</table>

*Table 1: Element characteristics associated with manufacturing practices*
By understanding the practices embedded in both industries, the knowledge was used to analyze how bamboo practices compare to practices in the timber industry. The study also looked at existing bamboo and timber user practices to identify possible barriers and opportunities for its utilization. Also considered were timber producer interests and their experiences with bamboo. Their experiences and knowledge around bamboo were crucial to identify possible barriers and opportunities for bamboo in the German market.

Figure 4 (Theoretical Framework; Social Practice Theory adopted from Shove et al., 2012) represents the theoretical framework in which producer practices are in the center of the analysis. These focus on all elements. Due to time limitations of the study, timber consumer and producer perspectives towards bamboo were considered as neighboring practices and did not focus on each of the elements.

Figure 4: Theoretical Framework; Social Practice Theory adopted from Shove et al. (2012)
CHAPTER TWO

RESEARCH OBJECTIVE, STRATEGY, METHODS, DATA ANALYSIS & JUSTIFICATION
2. Research Strategy

The following chapter begins with an explanation of the aim and objective of the study. Afterward, the main research question and sub-questions are described. Then the methods used and the type of data collected per sub-question follows. Lastly, a justification for the methods used is explained. The chapter ends with an explanation of how data was analyzed.

2.1 Aim and objective of the study

The study aimed at understanding manufacturing practices of timber and bamboo and hence, to illustrate the potential for more extensive use of bamboo in dominated German woodworking practices. Identifying overlapping practices could serve as an opportunity to introduce bamboo (further) into the German market and thereby contribute to greener development in Germany and the promotion of less timber usage.

The objective of the study was to evaluate whether the elements of bamboo manufacturing practices meet the same practice-based perspectives of the timber industry and if not, what elements need to change to do so.

2.2 Research question and sub-questions

Main Research Question;

What is the potential of more extensive use of bamboo in woodworking practices?

Sub-Questions;

1. What are (the key elements) of timber and bamboo woodworking practices in Germany
   a. according to literature?
   b. according to practitioners?

2. What are views on the integration of bamboo?
   a. according to woodworkers
   b. according to consumers?
2.3 Research Design

Due to the exploratory nature of the research, a qualitative research design was chosen. According to Patten and Newhart (2017), qualitative research is useful to approach themes that have not been explored adequately yet. Since the study explored embedded manufacturing practices and trends for which data was not sufficiently available, qualitative research seemed most applicable.

2.3. Research Methods and Justification

The following table lists the research questions, their corresponding data collection methods, the type of data used to analyze as well as the theoretical framing (see table 2; Summary Research Methods, Data and Theoretical Framing)

<table>
<thead>
<tr>
<th>Research-Question</th>
<th>Method</th>
<th>Data</th>
<th>Theoretical Framing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Research-Question</strong></td>
<td>Multi-method (see below)</td>
<td>(see below)</td>
<td>Social Practice Theory</td>
</tr>
<tr>
<td>What is the potential for more extensive use of bamboo in woodworking practices in Germany?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sub-Question 1</strong></td>
<td>a) <strong>Desk research</strong> was used to provide insight into existing manufacturing practices.</td>
<td>a) 14 scientific articles, 17 producer websites</td>
<td>Social Practice Theory</td>
</tr>
<tr>
<td>What are (the key elements) of timber and bamboo woodworking practices in Germany</td>
<td>b) <strong>Semi-structured interviews</strong> were used to understand manufacturing practices from the timber and bamboo industry (see Appendix 1 for a full list of interviewees)</td>
<td>b) 17 interview transcripts</td>
<td></td>
</tr>
<tr>
<td>Research-Question</td>
<td>Method</td>
<td>Data</td>
<td>Theoretical Framing</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------</td>
<td>------</td>
<td>---------------------</td>
</tr>
<tr>
<td><strong>Sub-Question 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What are the views on the integration of bamboo?</td>
<td>c) <strong>Follow up interviews</strong> were used to understand timber producer practices towards bamboo practices</td>
<td>c) 17 interview transcripts</td>
<td>Social Practice Theory</td>
</tr>
<tr>
<td>b) according to woodworkers?</td>
<td>d) <strong>Short-structured interviews</strong> were used to understand consumer wood product purchasing criteria and their interests in purchasing bamboo products</td>
<td>d) 40 (short) interview transcripts</td>
<td></td>
</tr>
<tr>
<td>c) according to consumers?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Summary research questions, method, data and theoretical framing

2.3.1. Justification Research Design and Methods

**Sub-Question 1.a** was answered with desk research as it helped to gain a broad understanding of existing knowledge of timber and bamboo practices. Therefore, a mix of scientific literature and data available on timber and bamboo producer websites was collected. Data from producer websites was used because it provided information on current manufacturing knowledge and trends.

**Sub-Question 1. b** was answered with semi-structured interviews. These were used to receive knowledge of current manufacturing practices and trends that were less likely available in the form of literature. Using semi-structured interview questions (see Appendix 2) ensured that each of the interviewees provided an insight into different manufacturing practices per element. It also enabled the researcher to ask follow-up questions such as for clarification purposes.

Due to the particular focus on practices, woodworkers (German: Schreiner) were mostly interviewed. They were interviewed because they are very knowledgeable about product processing and make up a significant market segment with almost 40,000 wood workshops registered in Germany in 2018 (Statista, 2018). Since bamboo products are mainly produced in tropical countries, manufacturers that are engaged in the German bamboo supply chain were also interviewed.
Lastly, manufacturers were identified by making use of snow-ball sampling and by searching for them in the web (Google, LinkedIn, Facebook). Search terms such as “bamboo/timber woodworkers, bambo/timber products” were used to identify manufacturers.

To answer **Sub-Question 2.a**, the same woodworkers were interviewed using unstructured interviews. According to Patten and Newhart (2011, p. 161) “unstructured interviews may be used in exploratory research when flexibility is needed to allow interviewees to bring up information that matters most to them.” Since the aim of the follow-up interviews was to identify the views of wood manufacturers towards the utilization of bamboo, unstructured interviews were most promising. To avoid response bias, the interviewees were not informed about that the research also involving bamboo.

To answer **Sub-Question 2.b**, short structured interviews (see Appendix 5) were conducted. These were structured because the interviewer was only interested in understanding the most important criteria for consumers to purchase timber products and to receive information about their feelings related to the purchasing of bamboo products.

**2.4 Data Analysis**

**2.4.1 Desk Research**

Information from different producer websites and scientific literature were analyzed per element (see Table 1: Elements and Description associated with Manufacturing Practices of the theoretical framework). Since it was difficult to retrieve information for the element “meaning” from literature about bamboo, attention was paid to adjectives that were used to describe the characteristics of it on producer websites. Once each element was explained, a table was created to summarize them.

**2.4.2 Interviews with timber and bamboo industry**

The interviews were transcribed and printed. Once they were printed, the text was color-coded with three different colors. Each color corresponded to a different element as defined by theory; orange for competences, blue for meaning and green for material. Elements that were difficult to separate were underlined with multiple colors (see Appendix 3: Color coding example).

Once all interviews were color-coded, excel tables were created in which the different interview outcomes were grouped per interviewee and element (Nr. 1 to Nr. 8; timber interviewees and Nr.9 to Nr. 17 bamboo interviewees) and summarized (See Appendix 4: Example to illustrate the summaries of the interviews per element). In sub-chapters of the result section, the elements of bamboo and timber were then separately analyzed and connected. In the discussion chapter, the elements of bamboo and timber were finally compared with each other.
Following the analysis of each element, a short segment follows in which the salience of specific element characteristics is illustrated. Unlike with the outcomes of the desk research, certain element characteristics were mentioned more frequently during the interviews. Characteristics that were mentioned more often were important to point out because it was assumed that specific element characteristics were more or less established in practices. The elements were highlighted depending on their level of salience (see Figure 5: Grafik used to illustrate element salience). Element characteristics which were mentioned by more than four interviewees were highlighted in dark color, three with a lighter color, two with even lighter color and one with the lightest color (see Figure 5: Grafik used to illustrate element salience).

Different colors were used to differentiate between elements. Blue was used for the element “Material,” green was used for the element “competences” and yellow was used for the element “Meaning.” Due to the time limitations of the study, the connections between various elements were not illustrated in the graphic but explained in the text. Figure 6 (Element Salience) illustrates an example of element variance and salience.

2.4.3 Interviews Ikea
The IKEA interviews were also color-coded. Depending on the different perceptions of timber users towards bamboo, different colors were used. In total, four colors were used, which resulted in the categorization of four groups. For each group, a summary was written regarding the groups’ potential interest or disinterest in buying bamboo products as well as its’ purchasing criteria for wood products. For the discussion section, two separate tables were created in which the key terms addressed in all groups were listed. The different timber purchasing interests were then compared to purchasing interests for bamboo products.
CHAPTER THREE

RESULTS
3. Results

This chapter lists the results of the desk research and interviews which are answered per sub-question (see Figure 5; Summary of Research Results per Sub-Question). The first part (3.1.1-3.1.8) answers Sub-Question 1 a. (SQ1.a) by listing the outcomes of the desk research. It firstly analyzes bamboo practices and then timber practices in the following order: Meaning, material and competences. After each section, a short summary follows which summarizes the main practices in the form of a table and text.

A similar scheme follows in the next part (3.2) in which Sub-Question 1.b. (SQ1.b) is answered by analyzing the interviews separately per bamboo and timber manufacturing practices. Once each element is analyzed, a graphic illustrates the connection and salience between these.

Section 3.3 (Sub-Question 2c. [SQ2. c.]) answers how timber manufacturers view the integration of bamboo into their practices. The last section (3.4) answers Sub-Question 2.d. (SQ2. d.) by illustrating the view of consumers towards bamboo. Figure 7 illustrates the caption per Sub-Question and section.

![Diagram](image-url)

*Figure 7: Caption per Sub-Question and sub-chapters*
PART ONE

3.1. Key elements of timber and woodworking practices according to literature

This sub-chapter describes the different elements of timber and bamboo. Literature is used to provide a basic understanding of the different material characteristics and practices used to work with as well as to transform material. It is also used to illustrate existing trends around timber and bamboo. Knowledge from producer website, for instance, was used to understand different feelings related to bamboo and timber.
The following sub-chapter begins with providing a background into current German producer perspectives towards bamboo by analyzing different feelings associated with bamboo. Further, literature is used to provide a general background into mechanical and material characteristics of bamboo. Literature then also points out certain know-how that is important for processing and work with bamboo.
3.1.1 Bamboo Meaning

Bamboo is advertised as a strong and durable material. Because of that, it seems well suited for flooring. Due to its ring-like structure, it is also advertised for its unusual appearance, fast growth and sustainable features (Holzboden-Direkt, 2019). The bamboo flooring exporter Moso (2019) promotes bamboo flooring products as ecological, strong and durable. Bamboo flooring is also advertised for its distinctive look and its suitability as industrial flooring. It is further described as an alternative resource to flooring made from protected tropical timber.

According to the bamboo producer Bambus-Freunde (2019) bamboo is also viewed as an exotic material, which offers homeowners a cozy and comfortable atmosphere. It is also described as durable and suitable for indoor and outdoor products such as for tables. Besides, bamboo is highlighted as a suitable alternative to tropical timber.

Another website, called Schoenerwohnen (2019) also describes bamboo as a sustainable material. It is also stated that "in terms of stability and durability, bamboo furniture is sometimes even superior to conventional wooden furniture" (Schoenerwohnen, 2019, para 1). Also described are its multiple uses as various products can be created from bamboo. Special about bamboo is its quick growth, its availability and the high quality of various products (Schoenerwohnen, 2019).

While producers are shedding a multifunctional light on bamboo, the perception of consumers towards bamboo material in Europe seems to differ. In a study conducted by De Bruijn (2006), IKEA visitors associated bamboo to Asia, nature, panda, woody, tropical, and cheap. It was least related to warmth, flexibility and furniture. Bamboo products were further associated with handicrafts instead of industrial products such as flooring. Only 28% of the interviewees associated it to a slightly high end, slightly innovative and quite warm resource.

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For some years bamboo parquet has been one of the most popular floor coverings of the Germans. No wonder: bamboo is surprisingly hard and resistant, it is also well suited for use with underfloor heating and has an unusual appearance with its ring structure. In addition, the bamboo parquet convinces nature lovers not only with its beautiful, natural appearance - but also with relatively environmentally friendly production. Finally, bamboo grows much faster than all known woods (Holzboden-Direkt, 2019, para. 1)
3.1.2 Bamboo- Material

Bamboos’ versatile reputation and images likely derive from its unique mechanical characteristics. It is one of the fastest-growing plants in the world (Embaye, 2000) with up to one meter of growth per day. Overall the height of bamboo ranges between 10 to 40 meters (Scurlock, Dayton & Hames, 2000). Its fast growth and significant height make it a favorable resource among bamboo producing countries such as China where “a hectare of commercially used Moso bamboo forest can produce 6 to 10 tons of fresh culms a year “ (Jinhe, 2001, p. 4).

Bamboo, in general, grows well in tropical and subtropical regions such as Africa, Asia, South and Central America where it is also naturally abundant (Mirmehdi, Tonoli and Hein, 2016) (see Image 1: Bamboos’ Abundance). It can also grow in some regions of Southern Europe. According to the Company BambooLogic E.V.(2019), the climate in Southern Europe such as Spain and Portugal, is perfectly adapted for the growth of bamboo.

Bamboos’ distinct look derives from its unique growth structure. According to the website BambooBotanicals (2019), bamboo grows in different segments known as internodes, which are separated by nodes (see Image 2: Bamboo Anatomy). The nodes of the bamboo culm are very distinct and often visible in bamboo products such as flooring (see Image 3: Bamboo Flooring). Blue circles highlight the nodes in Image 3.
Bamboo is also favored for its color variance as it grows. Different bamboos have different surface colors, with the majority of bamboos being thoroughly green. However, there are various other species such as tiger bamboo or black bamboo which differ in their surface patterning as oppose to largely commercially used bamboos like Moso bamboo (See Image 4-6: Bamboo Species and surface patterning).
As bamboo dries, it loses its color, which results in a natural light color of its pole (see Image 8; Dried Moso Bamboo). Some bamboos like tiger bamboo are likely to keep their surface patterning which is visible on the outer layer of the bamboo pole (see image 7: Dried Tiger Bamboo), but not in the inside.

The surface patterning (see image 7 and 8) is not thoroughly visible in the culm wall as with timber. Reasons for that are the mechanical properties of bamboo. According to the website Bambooimport (2019), bamboo has no vascular cambium layer; a layer that supports the growth of a tree per year and is responsible for the formation of rays. Since bamboo reaches its full growth within one year, bamboo only consists of an inner and an outer wall which is not divided by rays (see Image 9: Bamboo Cross Cut) (Liese, 1998; Trujillo & Lopez, 2016).
Although bamboo has no rays, the “look” of material can be altered through different cutting and gluing methods of bamboo strips. The grain of a species is more visible when its strips are vertically glued together instead of horizontally. Horizontal alignment highlights the typical nodal character of bamboo (see Image 10: Horizontal and vertical glued bamboo boards) (Bambooflooringcompany, 2019; Ambientbp, 2019).

*Image 10: Horizontal and vertical glued bamboo boards (Ambientbp, 2019)*
3.1.3 Bamboo Competences

Another material characteristic of bamboo is its high starch content, which makes it very attractive to insects, termites and fungi. Because of that, bamboo needs to be treated rapidly after harvest (Liese, 1980; Guadabamboo, 2019). Hence, it is important to have knowledge about the different treatments properties and their applications. According to Liese (1980) and the bamboo exporter Guadabamboo (2019), for products such as flooring, heat treatment is frequently used.

Through heat treatment bamboo poles are heated in specialized laboratories to remove any moisture (Shangguan, Gong, Zhao and Ren, 2016). During that process, the natural sugars of bamboo caramelize. This creates a color variance in the material. Since the natural sugars can be used for treatment and to create color variance, heat treatment in the form of caramelization is frequently used for the production of bamboo boards (Bestchina, 2019; CFI, 2019).

For the production of bamboo boards, bamboo is usually treated after bamboo poles are cut into small strips. According to the company Bambooflooringcompany (2019), these strips are typically heat dried through caramelization or cooking, pressed and glued together. Depending on the desired grain, strips are either vertically or horizontally glued together. The typical character of bamboo boards with visible nodes remains.

It is also possible to create an alternative type of grain in which the nodes are less visible such as with strand woven bamboo. Strand woven bamboo requires a different process than strip laminated bamboo. A reason for that is that the technique focuses on bamboos' fibers instead of the strips. To produce strand woven bamboo, it is primary crushed and “machine – shredded to pull out and isolate its strong fibers. These fibers are then pressed by steel hydraulic presses and subjected to heat until they form extremely dense logs. Once these logs are cured, they can be milled and fabricated” (Thespruce, 2019, para 6). This process enables an individual and modern bamboo flooring design in which the nodes of bamboo are less visible and different colors can

Image 11: Different types of strand woven bamboo (CFI, 2019)
be created (See Image 11; Different types of strand woven bamboo).

Ordinary horizontal bamboo flooring looks like pressed bamboo, despite any staining or other surface treatments. The coloration might say walnut or oak, but the patterning definitely says bamboo since the bamboo's culm (stalk) and distinctive nodes (similar to knuckles) are visible.

Yet anyone purchasing strand woven bamboo flooring and expecting that their floor will look like bamboo might be disappointed. Early in the production process, the bamboo loses its iconic look. (The Spruce, 2019, para 4&5)
3.1.4 Summary of bamboo elements

Bamboo, in general, grows well in tropical regions where it covers large areas. Bamboo grows in various colors but loses the color after harvest. It is further distinguished by its nodal character, which is visible in the majority of materials such as flooring. While bamboo has a limited grain, it can be altered through horizontal and vertical alignments of bamboo strips. The grain can also be altered by using strand woven technologies.

Since bamboo has a high sugar content, bamboo needs to be treated rapidly after harvest. If not treated immediately, it can attract fungi and other parasites, which leads to material deterioration. For the production of flooring, heat treatment is frequently used. Heat treatment is an integral part of the processes that involve the production of bamboo boards. Bamboo boards are, for instance, produced by cutting the poles into strips which are then glued and pressed together. They can also be produced with strand woven technology which focuses on the bamboo's fibers instead of its strips.

German producers seem to appreciate bamboo for its fast-growing character and its mechanical features such as strengths and lightness. It is also viewed as a sustainable alternative to tropical timber. The image of consumers towards bamboo likely differs as consumers relate bamboo rather to handicraft instead of an industrial product. Key features per elements are summarized in Table 3 (Key Features per Bamboo Elements).

<table>
<thead>
<tr>
<th>Material</th>
<th>Competences</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Hollow</td>
<td>• Treatment</td>
<td>• Fast-growing</td>
</tr>
<tr>
<td>• Tropical</td>
<td>• Mechanical Grain processing</td>
<td>• Sustainable</td>
</tr>
<tr>
<td>• Limited grains/colors</td>
<td>• Vertical/horizontal layering</td>
<td>• Strengths</td>
</tr>
<tr>
<td>• Various grains/colors</td>
<td>• Cutting</td>
<td>• Hardwood</td>
</tr>
<tr>
<td>• Fast growth</td>
<td>• Weaving</td>
<td>• Asian</td>
</tr>
<tr>
<td>• High starch content</td>
<td>• Gluing</td>
<td>• Handicraft</td>
</tr>
<tr>
<td>• Nodal character</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Key Features per bamboo element
This sub-chapter focuses on tree species that are used for product production in Germany. Reasons for that are their large applications in wood practices and processing. While there may be differences between tropical and non-tropical timber, it is assumed that mechanical properties of trees are similar between various species such as their annual growth. Specific characteristics may still differ such as the tree grain or speed of growth which varies between species. Furthermore, the content of this sub-chapter differs from the previous sub-chapter. Reasons for that are the different processes involved in both resources, but also the material characteristics.
3.1.5 Timber Meaning

According to Brockmann (1996), timber emits a cozy and warm environment. In a study conducted with Bavarian building owners, wood was associated with "nature," "forest," "warmth," and "cozy dwelling" (Brockmann, 1996, p.68). The authors Gold and Rubik (2019) which aimed at exploring consumer images with timber as construction material, discovered associations to timber with; aesthetics, well-being and eco-friendliness (Gold & Rubik 2019).

In another study in which feelings were related to materials, wood was perceived as one of the "functional materials that provide sensorial and expressive gratification" (Grippa, Rognoli & Levi, 2012, p. 9). Different materials such as plastic were perceived as boring due to material “repetitiveness through which people experience materials and a lack of new sensorial information” (Grippa, Rognoli & Levi, 2012, p. 9).

In further German literature, wood is associated with a renewable resource which can be transformed into various new materials. It is a resource that has been used for centuries in raw form or processed forms. It is also viewed as an excellent resource as it grows steadily in the same quality over a set period (Glasner & Ott, 2013).

In Glasner and Ott (2013), timber is related to a CO2 neutral resource. The authors also relate wood to warmth, aging in dignity, fragrant smells, and safety as the sounds of cracking wood can have a warning effect. The authors highlight that “the wood of the stone pine is even said to slow down the heartbeat and thus provide “cool heads “ - a quality appreciated by many Alpine region hosts who traditionally line their bar areas with pine wood, “(Glasner & Ott, 2013, p. 7).

On German producer websites, wood is promoted for its look with various beautiful grains. It is also promoted for its mechanical features such as for woods’ ability to regulate indoor climate (Holdboden-Direkt, 2019). It is further promoted as strong with valuable characteristics with key features being its beauty and durability (Innatura, 2019)
3.1.6 Timber Material

*Oak*

The wood of the oak is largely used for floorboards, furniture, ceiling, and wall panels. It should be logged around 240 years. Because of its long growth, it can be used as high-quality wood, which is frequently processed into parquet and flooring (German-Wood, 2019). Due to its hardness, heaviness and strengths properties (Holzvomfach, 2019), it is viewed as precious wood (Holzvomfach, 2019).

“It is extremely versatile, fulfilling the most stringent requirements concerning visual effect, strength, hardness, and durability of the type of wood to be used for both interior decoration and in building and construction “(German-Wood, 2019, para 3). Due to its durability and high quality, it is demanded in interior applications such as stairs, windows, frames, floors, and parquets (Holzvomfach, 2019). Also, the color of oakwood can vary between; light brown, biscuit and dark. An example of an oak board is illustrated in Image 12 (Oak board).

*Image 12: Oakboard (Holzvomfach, 2019)*

*Beech*

Beechwood is known to have one of the hardest properties in Europe. As appose to the oak, beech is usually logged between 100 and 140 years of growth (German-Wood, 2019). It is processed into furniture, stairs, and parquet flooring. Further, it is favored for its flexible, elastic, multi-faceted, attractive and decorative surface characteristics. “It is notable for its enormous pressure, tensile, bending and shear strengths and at the same time, lightweight, which makes it suitable for hard, resistant surfaces, “(German-Wood, 2019, para 7).

On the website Holzvomfach (2019) the beech is also highlighted as one of the most demanded
woods due to its strengths and smoothness. Because of that, it is heavily demanded in furniture production. (German-Wood, 2019; Holzvomfach, 2019). An example of a beech board is illustrated in Image 13 (Image 13: Beechboard).

Other tree species that are frequently used such as the ash tree is, for instance, known for its strength’s property and elasticity. Ashwood is also known for its distinct grain, which makes it a favorable wood for interior design. Wood from the chestnut tree is favored for its hardness and elastic features. The spruce is preferred for its fast growth (Holzvomfach, 2019). Differences in the grains of species make them more or less favorable for production (see Image 14-16; tree grains per species).

The reason for the different types of grain is the annual growth of trees. Trees do not mature within one season but mature throughout several years, which results in the formation of tree rays (Franklin & Mercker, 2009). Depending on the growth of the tree, the look of its rays can vary per species and season (see figure 16: tree ring growth) Therefore, differences in material grain such as in timber boards are visible (see images 14-16).
3.1.7 Timber Competences

Since trunk diameters are large, logs need to be semi-processed after harvest. This is usually done in sawmills where logs are sawn into boards and subsequently dried. The drying should reduce the wood moisture content between 12 and 24 percent. The processing of logs into boards previously to the drying is relevant because the drying of timber boards take less time than the drying of entire logs. If wood is not dried well or correctly, it can result in cracks, deformation and fungi (German-Wood, 2019).

Before timber boards are further processed, stains, oil and dirt should be removed. Afterward, a coating can be used, which supports the adhesiveness and the lifespan of the material (Erler, 2013). In the next step, laze can be applied. Transparent glaze maintains the natural look of the wood; its structure, grains, and branches. The look can also be altered by using laze with pigments (Erler, 2013) or laze with different features such as silky, glossy and matt (Erler, 2013).

Depending on the type and amount of glaze used, more or less caution should be paid. If laze is applied too thick, it is difficult for wood moisture to condensate. This could lead to the development of fungi or cracks in the material. If transparent laze is used, there is little protection from UV light, which could lead to discoloration of the material (Erler, 2013).

Once these steps are carried out, wood can be further processed. According to the wood manufacturer German-Wood (2019), it can be cut, glued and transformed into the desired product such as for the production of timber boards.
3.1.8 Summary of timber elements

Timber is largely favored for its durable and robust mechanical properties. It has versatile features, which allow for various product production. It also has multiple grains and colors. Grains which include rays are occurring through annual tree growth. Since there are various species, with different growth patterns, grains and colors vary per tree species.

In terms of processing, there was no particular mentioning of treatment other than heat treatment to remove the moisture content of wood. For the processing of timber, logs are sawn into smaller boards which are then dried. Laze can be applied with either transparent or pigmented color. Afterward, wood can be processed into the desired product. Then it can be transformed into the final product.

Timber is appreciated for its warmth, its cozy feelings and renewable features. It is also associated with aesthetics, well-being, nature and forest.

Table 4 (Key features of timber elements) summarizes the key differences between the elements material, competences and meaning

<table>
<thead>
<tr>
<th>Material</th>
<th>Competences</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Durable</td>
<td>• Gradual treatment</td>
<td>• Warmth</td>
</tr>
<tr>
<td>• Versatile</td>
<td>• Immediate use</td>
<td>• Cozy</td>
</tr>
<tr>
<td>• Grains</td>
<td>• Highlighting of grain using laze</td>
<td>• Renewable</td>
</tr>
<tr>
<td>• Slow growth</td>
<td>• Cutting</td>
<td>• Functional</td>
</tr>
<tr>
<td>• Color variance</td>
<td></td>
<td>• Aesthetics</td>
</tr>
<tr>
<td>• Solid</td>
<td></td>
<td>• Well-being</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Nature</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Durable</td>
</tr>
</tbody>
</table>

Table 4; Key features of timber elements
PART TWO

3.2 Key elements of timber and woodworking practices according to interviewees

This sub-chapter provides an insight into German timber and bamboo manufacturing practices. The outcomes of the interviews illustrate different producer preferences and ways of working with timber and bamboo. They also illustrate different reasons for the use of timber and bamboo by manufacturers such as associated feelings towards certain materials.

The majority of interviews were conducted with wood manufacturers. They usually purchase prefabricated timber or bamboo boards which are processed into a final product. There are also a few woodworkers that process timber logs. Most of their work is done by hand, which means they use small machinery to process the material. They also have a closer connection to customers as oppose to customers at IKEA. A reason for that is that customers usually order products that are individually suited to their homes. Such a product could be a wardrobe which is adjusted to sloped ceilings.

[References in the following sub-chapter are made with numbers. Each number is related to an interviewee (see Appendix 1)]
The following sub-chapter provides an insight into existing manufacturing practices of bamboo. The insight deprives largely from woodworkers who adopted bamboo into their timber manufacturing practices. The insight also includes manufacturers who are engaged in international bamboo product supply chains and sell their products on the German market. They were included because the majority of bamboo products are produced in the tropics and further processed in Germany. Among others, the insight of an Ethiopian enterprise that currently sells products on the Dutch market and is working on their product introduction in the German market was also considered. They were included because their product design will remain the same for the German market. The enterprise was also included as it has a valuable view on bamboo as tropical timber alternative.
3.2.1. Bamboo- Meaning

The interviewees appreciated bamboo for its multi characteristics; its positive charisma and appearance (9), beautiful look (10) nice esthetic (11), tropical timber alternative (12,17), a warm resource to work with (12), sustainable (9,14,15,17), interesting growth nodes (13), versatile characteristics (17) and strengths (9,10,11,13,14,16).

Although bamboo was perceived as a sustainable resource, its mechanical characteristics were more important for its utilization. “The esthetic of bamboo products is more important for customers. Especially if you are at home all day and have to look at it. For a lot of people, the robustness and hardness play a crucial role. Sustainability plays less of a role for them” (15).

Another interviewee also favored bamboo for its strengths characteristics (10), but the interviewee also perceived it as rather expensive. A reason for that is that woodworkers usually do not process bamboo culms. Instead, they process three-layered bamboo panels. “Because so many layers need to be added for the production of these panels, it becomes very expensive, while bamboo itself is actually a cheap resource. But for flooring, it is particularly great, because it is very very hard ” (15).

Due to the high processing and transportation of bamboo boards to Europe, the price of bamboo boards was perceived to become expensive. It is almost as expensive as other woods and likely affects the material choice of manufacturers. “A 20mm bamboo board costs 87, 35 Euro per square meter, beech board costs 103 Euros per square meter and an Oak “knotty” board costs 170 Euros per square meter “(12). Next to costs, another interviewee perceived the supply chain as in-transparent and it was favored more if bamboo could be sourced in Europe (14).

It was also mentioned that some customers do not favor bamboo because it does not have the solid wood characteristics “People do not like the bamboo patterns” (15). On the other hand, some customers favor bamboo because of its sustainable and nodal character (9).

Unlike the other interviewees, bamboo has particular value for the Ethiopian bamboo product supplier. They view it as a versatile plant, to which any kind value can be added. It can also be scaled up quickly. In addition, timber takes longer to grow and since bamboo can be harvested after five years, it is economically more attractive then timber. “And when you look up tropical timber, it is a controversial to use resource. There are issues with transparency, especially around tropical timber and in fact, we are going to market outdoor decking products which have the same timber like properties and can replace it “(17).
Figure 8 (Salience of the element material) summarizes the above and illustrates that the majority of manufacturers associated bamboo to material strengths and sustainability. Other associations were scattered.
3.2.2 Bamboo – Material

Bamboo manufacturers largely (10, 12, 14, 15, 16) utilize pre-fabricated bamboo panels which are further processed. These bamboo panels are ordered and supplied by dealers in Europe (13) such as the Netherlands (15, 16) or Italy (13). While the majority of bamboo manufacturers were not aware of the origin of the bamboo boards, a few pointed out that these are produced in China (9, 14, 15). One enterprise interviewed, produces bamboo flooring in Ethiopia. Besides bamboo boards, there was also one bamboo manufacturer who imports bamboo poles and sells these on German markets (13).

The type of bamboo species used to produce bamboo boards was less known. Two manufacturers highlighted the frequent utilization of Chinese Moso bamboo (9, 11) with the Ethiopian enterprise utilizing local highland bamboo, namely Yoshina Alpina. It was said that Moso bamboo is favored for production because it can reach a height of 18-25m with a diameter of 20cm and a wall thickness of 26mm (9). These type of bamboo species cannot grow in Germany due to its tropical growth characteristics (9,13).

“Bamboo grows around the equator and we use it from China, Cambodia and Vietnam. Guada bamboo from South America is also great. However, the bamboo industry in South America is not well researched yet from a technological perspective. China, on the other hand, has a well-established bamboo industry with the largest bamboo forests being located in China, but also Cambodia and Vietnam “(9).

Once poles are harvested, they should be rapidly treated (17). A reason for that is the high moisture content, which leads to a quick decay (9). The high sugar content attracts fungi rather quick, “so we need to process it fresh and then dry it to stabilize it” (17).

While there was no bamboo pole processing manufacturer, there was one who sold imported and untreated poles on the German market. The manufacturer mentioned that bamboo reacts strongly to its surrounding humidity and if not treated and processed well, it can easily break. Bamboo, a tropical grass, is adjusted to high air humidity which is not present in Germany. Therefore, bamboo moisture evaporates quickly. This leads to rapid splitting and breaking of the poles (13).

Two interviewees also highlighted that a lack of proper material treatment could lead to negative consumer perception of bamboo in general. This particular accounts to customers who purchase untreated bamboo furniture in the tropics and import it or customers who purchase cheap bamboo furniture in Germany (9,13) “Customers complain about cracks in their cheap furniture than those who purchase more expensive and well-treated bamboo furniture in Europe” (13).
This concern seemed less relevant for manufactures who purchase bamboo boards. Most of the bamboo boards arrive in a treated and preliminary processed form such as in the form of a three-layered wood panel (Germ: Dreischichtplatte) (10, 11, 12, 14, 16). Since these panels are similar to wood boards, the industry is able to process bamboo panels just as wood boards (10).

Currently, panels are available in two colors, which is light (carbonized) or very light (10, 12, 14) such as cappuccino color (9). Bamboo colors were also referred to as light and yellow and compared to the colors of the spruce, maple and in the caramelized form to the oak.

Bamboo panels can also only be purchased in limited styles. In both styles, the nodes are visible (15). To create a different look, bamboo strips can be glued together horizontal or vertical (14). However, limited types of grain and the present look of nodes is a disadvantage for its utilization. One manufacturer who favors bamboos’ mechanical properties uses bamboo OSB plates as a foundation. Then visual, more appealing material is attached (11).

Unlike German woodworkers, exporting enterprises mentioned the various color variances and designs that are available on the market (9, 17). It was, for instance, mentioned that there are methods on the market that can create various color patterns but also grains (9, 17). These would make bamboo look more like timber (9, 15, 17).

Further, bamboos’ material strength (10, 11, 13), related stability (12), hardness (10, 13), density (14) were key mechanical features. Bamboo was even perceived to be a stronger material than domestic German wood (14). Bamboo flooring weights similar to oak flooring with both weighing around 700kg per cubic meter. Depending on how bamboo is processed, it can reach around 900-1200 kg per cubic meter, such as with strand woven bamboo (11, 17).

Although bamboos strength was highlighted as a key advantage, its small fibers were also mentioned as a disadvantage (10). Due to the fibers, bamboo appears to break easier when cutting it along the glued fibers (10). Another disadvantage mentioned was the fact that although bamboo is strong, it needs to be glued, which is an optical disadvantage over solid wood (12, 16). On the opposite bamboo was again favored for not having tannic acid or other oils, which makes it favorable to process and work with it (11). The latter is favored for customers with oil-based wood allergies. Lastly, it was also favored because of the similar processing to wood boards (9, 10, 15).

Figure 9 (Salience of bamboo material) summarizes the above and illustrates that bamboo was mostly processed in the form of a three-layered bamboo panel but not in the form of culms. It usually is available in the form of set colors and grains. Most interviewees seemed to know that
it is produced in China. Bamboo is further appreciated for its strengths. Only one interviewee highlighted the technique of strand woven bamboo which seemed to be less known by other interviewees.
3.2.3 Bamboo – Competences

Since bamboo can be processed differently, different competences are needed. Bamboo boards require less effort to process than bamboo poles. Bamboo boards, on the other hand, are produced in tropical countries where machinery is adapted to the processing and treatment of bamboo poles. In Germany, culms are less likely processed because it requires more effort than working with solid wood (16). “Bamboo needs to be cut first, pressed together under an extensive amount of heat which bears more effort than working with solid wood “(16).

The interviews highlighted two types of processing techniques for bamboo flooring; strand woven bamboo flooring (Germ: Faserverleimt) and stripe laminated flooring (Germ: Stabverleimt). For strand woven flooring, “bamboo culms are split into strips. In the next step, these strips are crushed into fiber mats. These are laid on top of each other and pressed under high pressure and temperature while adding resin as binder “(17). As bamboo is heated, it is also treated equally. To do so, bamboo fibers are put into a kiln which reaches between 160-200 degrees Celsius (17).

With laminated bamboo flooring, bamboo stripes are glued together. This promotes the typical natural look of bamboo in which nodes are visible on the boards (9). To create a different look, bamboo strips can be glued together either horizontally or vertically (Germ: Längs und Quär Verleimung) (10). When glued together vertically, patterns can be created which highlight the natural grain of bamboo more. When glued together horizontally, the typical pattern of bamboo remains in which nodes are clearly visible. With both types of bonding, the nodes remain visible (11).

Depending on how bamboo is treated, the product color can be influenced. Firstly, bamboo can be cooked in a H2O2 solution. Through this form of treatment, bamboo maintains its natural light color (11). Secondly, it can also be caramelized (9, 10, 12, 17). Through caramelization, the natural sugar of bamboo is used to influence the color (17). For strand woven bamboo, “bamboo is thermally modified (11) and the stage defines the color. It happens in a kiln in the absence of oxygen. The duration in which bamboo is heated in the kiln is altered towards a certain color such as vanilla to dark coffee color or from cream to chocolate. With fiber mats, different colors can be mixed, which creates unique appearances “(17).

The color of bamboo can also be influenced by applying oil. “Once products are dried, they can be oiled. Oil can have different pigments, which makes bamboo flooring appear more like tropical wood” (17). However, bamboo can also be stained to create color variation (10, 11).
As appose to the processes that are involved in the treatment and production of bamboo culms, German woodworkers mentioned that they were able to use the same machinery and knowledge to process bamboo boards as with timber boards. (16, 15, 14, 13). Hard metal (14) or diamond-covered plates (15) are used to process bamboo and timber boards. Also, the same type of glue can be used for the gluing of bamboo (14). Adhesives include; formaldehyde or Melanin, Resin, PVC, EPI, or Kaurit (15). Once the bamboo panels are glued, they can be cut to the desired size, grinded and coated (14).

Figure 10 (Salience of the element competences) summarizes the above and illustrates that most competences are currently required for the processing of bamboo boards, which are similar to timber boards. Although there was general knowledge about the treatment of bamboo by caramelizing or cooking it, it seemed less applied by manufacturers. Woodworkers seemed to view it as more important to have competences related to the cutting, pressing, gluing and slicing of timber boards.

![Figure 10: Salience of the element Competences](image-url)
3.2.4 Bamboo elements connected

Bamboo was perceived as a sustainable material with interesting looks and beautiful characteristics. Due to its strong characteristics, it was favored for products such as flooring. Woodworkers also described design limitations. Currently, bamboo panels are available in only two colors and grains. These colors vary between “caramelized or cappuccino” color. Grains consist of the typical bamboo stripes that are either horizontally or vertically glued together. Because of the limited designs, bamboo is less favored for interior designs, which requires material variance.

Interviewees directly connected in the international supply chains were able to highlight processing techniques that can create variety in the designs of bamboo boards. Strand woven technology and special forms of heat treatment are used to produce light to dark-colored bamboo boards. However, German bamboo manufacturers were not aware of the latter and currently work with limited colored and grained bamboo boards.

In terms of the element competences; knowledge to process bamboo depended on the type of material to be processed. To process bamboo poles, it needs to be known that bamboo has to be treated rapidly after harvest. This is mainly done in producer countries such as China where semi-processed products are exported to Europe. Since German bamboo manufacturers mainly process bamboo boards, they need to know how to saw and glue these.

Bamboo was favored as production material for its strong mechanical characteristics. It was also featured for being a sustainable material with similar colors to German timber. Although bamboo was perceived as a cheap resource, it was perceived as expensive to work with material as it needs to be transported and heavily processed firstly.

Figure 16 (Element Salience), illustrates that the majority of elements were related to material characteristics, followed by competences needed and meaning associated with bamboo. Most frequently mentioned was the processing of bamboo boards. To do so, competences such as cutting, gluing and slicing of the bamboo boards are needed. Overall, bamboo was featured for being a hard and sustainable material.
Figure 16: Element salience
The following chapter provides the insights of practices established in wood manufacturing processes. The interviews helped in shedding light on important material characteristics but also ways in which timber is frequently processed.
3.2.5 Timber- Meaning

When directly asking wood-workers how they felt when they were thinking about timber or what the work with timber would mean to them, responses varied as follows; “nice in touch” (1), ecological, individuality in each piece, product created by nature which creates excitement, color creates a particular feeling, sustainable, warm feeling (2). Others also highlighted the warm feeling that wood creates but also the grains which create beautiful images (3).

Warmth was also addressed by another interviewee but also the ability to have a natural product in a room (4). It creates nice feelings (4). Wood also generates a sense of beauty due to its grains, but also a cozy feeling with an acoustical atmosphere that has a unique sound. It was also perceived as a beautiful resource to work with (5). It was related to romance (6) and liked for its look (7). Lastly, wood was also highlighted to bring warmth into a room which is different to looks, such as in hospitals (8).

Based on the interviews, timber seemed particular liked for its grain variance (8, 5, 4, 3, 2), which differs between species. The grain is influenced by the species but also the growth time. This affects the price of a certain timber material which again influences the demand for a certain species. There was also one interviewee who highlighted that clients who cared about sustainability favored hard and solid wood. This is more expensive as hardwoods grow longer than solid woods. Because of that it is less demanded (12).

In following Figure 12 (Salience of the element wood meaning) illustrates the elements mentioned most to least by interviewees. Frequently mentioned was the appreciation for grain variance and the fact that timber promotes warm feelings. Other associations to timber were scattered.

Figure 12 (Salience of the element wood meaning)
3.2.6 Timber Material

All interviewees used the oak and the spruce for production. Other tree species used included the beech (1,4,7,8), the cherry tree (1), the ash tree (3,5), maple (3,4,5,7,8) and tropical timber (1,2). While the majority of tree species used for production derived from Germany, some were also from other regions in Europe or outside of Europe (4, 8). Canadian oak was, for instance, favored for its unique yellow tint, which is unlike the German oak species (8). Tropical timber was favored for its look (1,2).

Wood was appreciated for its mechanical properties such as its strengths variance per species, flexibility and softness (1, 4, 5, 6,7,8). Depending on the strengths of a tree species, particular tree species were more or less favored for production. The oak, for instance, is known to produce hardwood (4,7) and is preferred for flooring (1) but also stairs (4) unlike softer types of wood such as the spruce.

On the other hand, hardwoods such as the oak typically take more time to grow than softwoods (2, 5,8). The growth time affects the price of the material, but also the availability. Over the last years, a price increase was observed by manufacturers for timber as a consequence of decreasing timber availability (5, 7,14, 12) such as the oak (12,14,5). Oak was also mentioned to become more expensive as it is demanded more as constructional timber (5).

In average, German timber is logged after 80 years of growth (17). The oak matures around 80-100 (2); 100-150 years (8) before being logged. Since certain species take longer time to mature than others, the price of the material becomes more or less expensive; Beech grows quicker than oak and is cheaper. According to one manufacturer, one square meter of beech board per 20mm diameter costs 103 Euros (12) which is relatively low in comparison to one square meter of oak “knotty” with 170 Euros (12).

Depending on the tree species, color and grain of the material vary as well. Maple, oak and beech were favored for their light colors (8) or the Canadian oak for its yellowish tint. Oak “knotty” was highlighted to become more fashionable again due to its “rustic” look for flooring (12). While colors are more set per species, grains more likely vary per species (1,2,8). Reasons for that are the different growth patterns of trees. Trees do not grow straight together but “round while running weirdly together at the top” (2). In addition, the growth speed of trees also affects the grain. Trees with a longer growth rate have less “drawings” (Germ: Zeichnungen) than trees that grow quicker. Maple, which grows quicker then other tree species, has rarely any structure. It is recognized for being a neutral looking wood (4).
Besides the above characteristics, woodworkers also favored wood because it is an “easy to work with resource” (2). However, it was more favored to process pre-fabricated wood boards instead of logs as the processing of logs requires more work than with wood boards (3,4,6,8). Benefits of wood boards include that they are already dried and processed into smaller boards which can be easier processed into a final product. This is unlike the work with logs in which manufacturers have to produce boards and dry these themselves firstly (4,6).

Working with wood logs and wood boards also requires that its moisture content is adjusted to its surface humidity (3, 4, 6). Since wood is an organic material, it moves with surface humidity (3). Wood can breathe and therefore stretches out or tightens as moisture is absorbed or evaporated by wood. Hence, the moisture content of wood material should be adapted to the humidity in the environment (4,6).

When working with an entire log, overall preference should be given to the inner parts of the tree known as sapwood (Germ: Splintholz) and the heartwood (Germ: Kernholz). Those are the inner parts of a tree and used mainly for production (6). The outer components, known as the bark, are not used and “peeled off” from the tree for further processing (8).

In terms of material quality, wood boards and logs should illustrate grain consistency. Also, the material should be free of damage (6, 3). One wood-worker highlighted that there could be a lack of quality if nails or other material are inside the logs. This can have a severe consequence on machinery such as frame saws which are used to process logs into boards (6).

Although there is a preference for high material quality, one interviewee favored wood with lower quality standards. The woodworker prefers wood with cracks and other malfunctions. This creates material uniqueness, which is favored among customers if processed well (3). Regardless of the type of wood, preference was raised for solid wood (German; Massivholz) (3,5,8,9).

There were only a few disadvantages mentioned for timber material. One interviewee mentioned that soft-wood is disadvantageous for products with excessive usages, such as flooring (4). Another disadvantage mentioned more frequently was tannic acid (6, 8, 9). Tannic acid of the oak can’t be washed off and needs to be worked off (8). Besides, tannic acid such as from the Robinia Tree can cause health damage during processing, such as when dust particles are inhaled (6). Lastly tannic acid can result in allergy reactions if present in products such as flooring (9).

In following Figure 13 (Salience of the element wood material) illustrates the elements mentioned most to least by interviewees. Visible is that the majority of woodworkers utilize oak, spruce, beech, and maple while largely having a preference for solid wood. Most woodworkers
prefer to process wood boards and appreciate wood for its mechanical properties such as hardness and softness.

Figure 13: Salience of the element wood material
3.2.7 Wood Competences

Woodworkers usually purchase timber boards (2,4,6,8) but also logs (6). Because of that, they do not need to have specific knowledge of the logging of timber. If they purchase logs, they need to know how to dry and process them.

Before logs are dried, they should be sawn into boards (2,4,6,8). This process usually takes place in sawmills where logs “are sawn into boards, stored in palettes and dried in chambers” (8). Pallets usually stay in those drying chambers for six weeks, where the moisture content is reduced to 8-12% (5,6,8). It is also possible to air-dry wood logs (2,8), but this takes between 2-7 years (8) or “simply too long” (6). If the moisture content of wood is not adjusted well, it can lead to material damage or malfunctioning (6,8).

If wood-workers decide to process logs, they need to know how to saw the logs into smaller boards and also how to reduce as well as how to measure the moisture content. They also need to examine the wood for its quality (2,3,4,6). Since this requires a lot of effort, the majority of wood-workers purchase pre-fabricated timber boards. Timber boards are then usually processed in the following order; slicing, sanding, coating, and oiling (8,7, 6, 5, 4, 3, 2). The processed parts should then be glued (7,4) and drilled (3) together.

Since wood has flawed characteristics, the coating is very important. If wood is not coated properly, it is more likely to absorb and store moisture. Also, if too much moisture is absorbed, it can result in the material turning moldy. Hence, the coating protects the material from absorbing moisture (3).

In general, wood-workers can use the same processes for different products with different timber species. However, using different cutting techniques or coating the material with different colors can influence the grain of the material. Depending on the direction in which wood boards are sawn, they can obtain a different type of grain (6,7) “like a flower” (7). Also, the color of the wood product can be changed through staining (Germ: Beizen) of the material (2,8). Overall the same machinery can be used for various products.

In following Figure 14 (Salience of wood competences) illustrates the elements mentioned most to least by interviewees. Visible is that the majority of woodworkers need to know how to saw, sand, coat, and oil the material. It should also be known how to process logs into boards. It was also important to know the accurate wood moisture content and to reduce wood moisture accordingly.
Figure 14: Salience of the element competences
3.2.8 Timber elements connected

There is a preference made for the work with timber as it is an ecological product. Since there are various timber species used, there is also variance in the type of product material due to different forms of grains and colors. Depending on the color and grain, which both are material characteristics, different types of feelings can be associated with timber products.

Mechanical characteristics such as grain and strengths depend on timbers’ growth structure. Very strong timber with particular grains such as oak “knotty” is rather expensive and also takes longer to grow then timber which is softer. Softer timber was pointed out to have fewer grains, which again makes it more favorable in terms of affordability but less favorable in terms of consumer preferences.

Although grain and color are determined by the mechanical properties of timber, it was also pointed out that these can be altered through different processing techniques. The color of the material can be altered by using different types of coating to create darker looks. This, on the other hand, can create different feelings associated with timber products. It was also highlighted that timber could be cut differently to highlight different types of grains or to make grains more or less appearing.

In addition, there were different preferences made towards the work with logs and wood board. Wood boards were simpler to work with because they already arrive semi-processed. Logs need to be processed completely, which also includes the cutting and drying of timber pieces.

Figure 20 (Salience of elements and their connection) illustrates that the majority of elements discussed related to the element material, which was similar to the element competences. The least characteristics discussed related to the element material. Most mentioned was the type of wood used, followed by the competences needed such as slicing, sanding, coating, and oiling. Depending on the species and the processing, different grains and feelings are created.
Figure 25: Salience elements
PART THREE

3.3 Views on the integration of bamboo into woodworking practices according to timber manufacturers

“Study the teachings of the pine tree, the bamboo, and the plum blossom. The pine is evergreen, firmly rooted, and venerable. The bamboo is strong, resilient, unbreakable. The plum blossom is hardy, fragrant, and elegant “- Morihei Ueshiba (Bambooz, 2019)

This sub-chapter explores the different views of timber manufacturers of bamboo. The purpose of this sub-chapter was to illustrate possible barriers and opportunities for the extended use of bamboo in German manufacturing practices.
3.3 Views on the integration of bamboo into woodworking practices according to timber manufacturers

Almost all woodworkers had experiences with the processing of bamboo boards (8). There was only one interviewee who did not work with bamboo. The interviewee criticized that it was difficult to apply oil on the material surface. The same interviewee also mentioned that it was difficult to glue bamboo stripes together unless heavily synthetic adhesive is used. “The adhesives can cause environmental harm” (8). Because of that, the interviewee decided not to engage in the processing of bamboo (8).

Other interviewees had different experiences with bamboo. They used bamboo for the production of parquet (1), flooring, furniture (5) and veneers (8). Favoried was its hard feature (5,8) and its quick growth (8,7,4). Another advantage highlighted was its colors as it is similar to other tree species. Light bamboo boards have a similar color pattern then the oak, which is browner tinted. Much lighter bamboo boards are similar to the color pattern of the birch and maple (3).

Regarding bamboo material, there was only one interviewee who had worked with bamboo poles (8). Other interviewees ordered bamboo boards for further processing (2, 3). The interviewee who worked with bamboo poles criticized that it was difficult to process because multiple adhesive bonds (Germ: Verleimungen) are needed to glue the different layers together. The interviewee also mentioned that “there is generally no disadvantage, just more effort because you cannot peel it off like with timber but really need to glue and cut it together” (8).

Bamboo was further criticized for its thin fibers, which makes it difficult to process (2). It was also criticized for its look with limited material variance (4, 5, 7). First of all, there are only a few colors of bamboo material available. Secondly, the stripe-like pattern with visible nodes is creating a “wild” (4) and restless look (5). One interviewee particular highlighted that with “projects and interior design variances are needed, but with bamboo, there is little variance so it cannot be used often. Wood grains are, for instance, important for customers but also color variance, but that is both limited with bamboo” (4).

Working with bamboo seemed similar to the work with timber. For processing, the same machinery can be used. The only difficulty seemed to be the fibrous structure, which requires more care during processing (6) but also the gluing of the bamboo strips (8). Another interviewee also mentioned that working with bamboo boards is beneficial because “it does not easily create dents which are important for furniture and flooring” (4).
Bamboo was further described as an attractive material (3) with beautiful looks (4). Although perceived as beautiful, it was also perceived as an expensive material which was argued to be based on the high processing expenses (4).

In addition, there seemed to be a lower demand for bamboo by customers (1), which was highlighted to be based on little knowledge around bamboo by the industry but likely also customers (4). It was perceived as an ideal ecological material if it would be composed of no chemical glues, no plastic surface and if it was beautiful looking (4). With bamboos current pattern, the latter would less likely be the case (4).

Lastly, there was also criticism of bamboos' ecological aspects (2,7). For instance, it was more favored to utilize wood as bamboo needs to be processed into strips and then glued. The opposite takes place with timber (2).

Overall there seemed to be a balance between positive and negative perceptions towards bamboo (See Table 5: Perceptual barriers and opportunities for woodworkers regarding bamboo utilization)

| Perceptional barriers and opportunities for woodworkers regarding bamboo utilization |
|---------------------------------|---------------------------------|
| +                               | -                               |
| Strong                          | Wild look                       |
| Durable                         | Less ecological                 |
| Mostly same machinery used then with timber | Difficult to work with         |
| Available in bamboo boards      | High operational cost           |
| Price similar then timber       | Very fibrous                    |
| Attractive                      | Limited design possibilities due to limited grains and colors |
| Wood-like color availability    | Lots of glue needed             |
| Distinct grain                  | More expensive than timber      |
|                                 | Limited demand                  |
|                                 | Cannot be peeled off like with timber |

Table 5: Perceptual barriers and opportunities for woodworkers regarding bamboo utilization
PART FOUR

3.4 Views on the integration of bamboo into woodworking practices according to timber users

This sub-chapter illustrates the interests of different purchasing criteria, customers have for buying timber products. It also analyzes how customers feel about the purchasing of bamboo products. The last aspect helped in understanding perceptions of customers towards bamboo and whether current bamboo products could meet certain timber product purchasing criteria.

Source: Laban, J. (2019)
3.4 Views on the integration of bamboo into woodworking practices according to timber users

The outcomes of the short interviews (see Appendix 5 – Transcript IKEA interviews) illustrate four different types of groups that 1. have already purchased bamboo products and are very interested, that 2. are positive about the purchase of bamboo products as long as it meets certain criteria, that 3. have no opinion and lastly that 4. do not like to purchase bamboo products. In following the interview outcomes are illustrated per group.

Group 1 - “Very positive about bamboo”

10 out of 40 interviewees were very positive regarding the use of bamboo furniture and already had purchased bamboo furniture in the past. Some mentioned positive features of bamboo such as “it looks good,” or it was liked because “it is very stable.” Others favored it because it is more hygienic than other materials. Bamboo furniture was, for instance, also liked because it is easy to refurbish due to its strengths.

Among this group, most favored features for deciding whether to buy a wood product were; natural look, light colors and materials like oak. It should fit well with other furniture and must be in the budget. It should be easily built together, have great quality, stable, great material health, ideally real wood but not too heavy and should be solid and transportable. Quality and price were also important purchasing criteria.

Group 2 – “Likely to purchase bamboo with conditions”

10 out of the 40 interviewees were not well aware of bamboo but seemed positive about the use of bamboo as long as bamboo furniture could meet their desired needs on furniture. In this group, general opinions towards the purchase of bamboo products were that “if it fits, why not buying it” or if it “looks good, it can be made of bamboo.” Overall it should fit into the rest of the design and furniture.

In this group most favorable purchasing decisions related to the general look of the product, its stability and look like solid wood, its functionality, and color. The majority referred to the importance of “the look.”

Group 3 – “No opinion about bamboo”

11 out of 40 interviewees were not well aware of bamboo and did not express any knowledge or interest regarding the purchasing of bamboo products. Many of them had no opinion about bamboo, or one interviewee particular did not know anything about bamboo.
Among this group, the most favorable purchasing decision related to color, like in the real world and with real wood, its functionality, wood-look, its stability, and quality, especially with children. Important was also its design. It should fit well together and it should provide a comfortable feeling.

**Group 4 – “Against bamboo”**

In total, 9 out of 40 interviewees were rather negative about the use of bamboo. Key reasons for not using bamboo were that its style does not fit into the homes of the customers. It is less favored because it is difficult to wash off things, and bamboo does not belong here, unlike domestic woods like the oak. Bamboo was also associated with an Asian instead of European product.

Among this group, most favorable purchasing decisions related to the functionality and look, real wood because of material quality and price, sustainability, practicality, and wood-like features.
In this chapter the outcomes of the research are discussed. It begins with answering sub-question one by analyzing the outcomes of the interviews and desk research with timber and bamboo. The outcomes are illustrated per element and lastly merged together. Sub-question two is then answered by analyzing the outcomes of the consumer and follow-up timber manufacturer interviews. The conclusion section then answers the main research question. This subchapter ends with further recommendations and the limitations of the study.
4. Discussion, Conclusion, Recommendations and Limitations

4.1 Discussion

The section begins with answering the first two sub-questions by combining the outcomes of the desk research with the outcomes of the interviews with manufacturers;

What are (the key) elements of timber and bamboo woodworking practices in Germany
a. according to literature?
b. according to practitioners?

4.1.3. Meaning

Desk research provided a broader image of feelings related to timber by Germans. It was promoted as a material which creates a cozy environment. It was also associated with nature, forest and warmth. In other literature it was compared to well-being, aesthetics and eco-friendliness. Timber was further perceived as an exciting material as it provides sensorial experiences. It was also referred to as a renewable resource.

When asking wood producers how they felt about timber, they also associated it to similar feelings such as those illustrated in the literature. Yet, their views seemed narrower by associating it to warmth, acoustic, nice in touch. They also referred to timber having individuality in each piece, which creates excitement. Color variance creates a particular exciting feeling with timber also being associated with romance and beauty.

Besides these characteristics, the relation between growth time, price, mechanical properties, and grains or timber were also important. Customers, for instance, appreciate hardwood, but hardwood is more expensive. Hardness was one character which was appreciated for certain tree species in literature and the interviews. However, it was most appreciated for bamboo. Because of bamboos’ strong character it was favored for flooring or material in which bamboo’s strong mechanical characteristics were advantageous.

Bamboo was further promoted for its durable characteristics. It is viewed as a strong, quick growing and sustainable material that can be used as an alternative to tropical timber. It was less associated with warmth, but more with lightness, longitudinal strengths and durability. Some websites also featured it for its natural, rustic, attractive, and appealing characteristics. However, one study conducted at IKEA in 2016, illustrated that consumers have different images of bamboo. In that study, consumers referred to bamboo as cheap material with little associations to engineered products such as flooring.
The outcomes of the desk research align with some of the perceptions of interviewees towards bamboo. The interviewees perceived bamboo as an interesting material with an evenly interesting character. When they thought about bamboo, they thought about sustainability, but also beautiful looks and charming characters. Although less favored for its look, it was strongly favored for its mechanical characteristics; hardness.

The Ethiopian based bamboo enterprise particular emphasized the use of bamboo as tropical timber, which also aligns with information retrieved from bamboo producer websites. The enterprise views bamboo as a great opportunity because it can be harvested quickly and transformed into various products. Therefore, it can serve as a potential alternative to tropical timber, which is perceived as controversial to use resource (17).

4.1.2 Material

Desk research pointed out that bamboo grows well in tropical and sub-tropical countries. This statement is supported by bamboo manufactures who also highlighted that the growth of bamboo in European countries is not well suited. This is contrary to the outcomes of the desk research, which illustrated that bamboo could also grow in Southern Europe such as Portugal and Spain. One interviewee argued that the amount of bamboo which is currently produced in China, as well as the type of bamboo used for commercial purposes, could not grow sufficiently in Europe.

Since bamboo is assumed not to grow well in Europe, it is currently semi-processed or fully processed in tropical countries and then exported to Europe. One interviewee pointed out that China is largely adapted to bamboo where most of it is processed for commercial purposes. This is unlike the German market where wood manufacturers are more adapted to the processing of timber.

While bamboo remains a tropical and foreign species, German manufacturers have or made experiences with the processing of bamboo. Almost all interviewees, including bamboo manufacturers and timber manufacturers, have processed bamboo in the form of bamboo boards. Literature and interviews point out that the processing of bamboo culms may be a challenge due to the need to treat bamboo almost immediately after harvest. According to literature and the interviews, bamboos’ high starch content makes it very attractive to fungi, insects and termites after harvest. Because of that, bamboo needs to be treated immediately.
Since bamboo should be treated immediately after harvest, it seems difficult to export it to Germany. One interviewee explained that although it is possible to export untreated bamboo culms to Germany, they are more likely to break. A reason for that is the climate difference and bamboos’ adjustment to a humid tropical climate. In Germany, this form of humidity is not present. This leads to the quick evaporation of moisture which is stored in bamboo and therefore, results in rapid splitting and breaking of the poles.

The latter differs from timber. Although timber can be treated, the need for immediate timber treatment, to avoid material deterioration, was not mentioned. Timber manufacturers, for instance, highlighted that it is possible to air dry timber for years and then use it for further processing. This differs from literature and the interviews in which the need for immediate bamboo treatment after harvest was illustrated.

Interviewees also pointed out that unlike with bamboo, the bark of timber can be “peeled off” and then processed immediately such as into solid timber boards. Literature and interviewees illustrated that this is not possible with bamboo. Bamboo culms are hollow and because of that, bamboo cannot be “peeled off” and then processed into “solid bamboo.” To produce “solid bamboo”, bamboo needs to be cut into strips and glued excessively which, according to German manufacturers, requires a lot of effort and is less ecological.

Since bamboo needs to be processed firstly, which is unlike timber, German bamboo manufacturers prefer the purchasing of bamboo boards. According to the German bamboo and timber manufacturers, these boards are similar to timber boards and supplied by dealers around Europe. Bamboo boards also have similar characteristics to timber boards’ and are known as “Dreischichtplatte” (English; Three-layer wood panel).

The processing of these three-layered bamboo panels was mentioned frequently by interviewees, but less likely in literature. The interviews with bamboo and timber producers pointed out that bamboo panels are only available in limited color and grains. According to the interviewees, bamboo panels are supplied in light (caramelized) or very light (cappuccino) color. In addition, bamboo panels are usually horizontally or vertically strip laminated which maintains the natural character of the bamboo culms. According to the interviewees, this bears a challenge for manufacturers as there is a demand for material variances such as in color and grain.

Unlike the interviews, literature provided more insight into the reasons for grain variance between bamboo and timber. First of all, bamboo has no cambium layer which differs from timber. This layer supports the annual growth of a tree per year. Since timber matures over multiple
years, various growth rings known as rays are visible in timber material. This differs from bamboo, which reaches its full growth height within one year. Therefore, it only consists of an inner and an outer wall which is not divided by rays but more or less characterized by its nodes.

Literature and interviews also pointed out that, depending on the type of wood used, its grain differs. One interviewee argued that even within the same timber species, different grains are created as “trees grows weirdly together” (2). Likewise, literature pointed out that the growth of trees is influenced by the growth during one season. This did not seem to apply to bamboo.

Neither interviews nor literature explained how timber or bamboo receive their natural color. The interviewees pointed out that there seems to be more color variance between timber species which according to the interviews and literature ranges from light to dark colors. Literature also illustrated that although bamboo can have various grains and colors, which are visible on the outer layer of the bamboo such as with tiger bamboo, these seem to diminish once dried. Because of these differences, it appears that bamboo material is available in natural light color and timber in greater color variance.

Interviews and literature pointed out that the color of timber material can be altered by using a laze. This was not mentioned in the literature concerning bamboo. However, one bamboo manufacturer who is located in Ethiopia highlighted that it is possible to alter the color of bamboo by utilizing pigments. This seemed possible when processing bamboo differently, such as with “strand woven technology.” With this technique, different grains can also be created. This type of technique and knowledge around color and grain variance was less known by German bamboo woodworkers. On the other hand, literature also explained the process of strand woven bamboo, but it did not illustrate that the color of bamboo could be altered.

Next to color and grain variance, there are also differences in the mechanical characteristics of timber and bamboo. Wood manufacturers highlighted that hard timber grows longer than soft timber. Hard timber is more used for materials that are exposed to more stresses such as stairs and flooring. However, the longer growth time also affects the availability of the material and because of that also the price. One interviewee provided a price example between the rapid growing beech and the slower growing oak; One square meter of beech board per 20mm diameter costs 103 Euros (12) which is relatively low in comparison to 1 square meter of oak “knotty” with 170 Euros (12).

According to the interviews and literature, bamboo matures quicker than various timber species with five years of growth. Interviewees highlighted that timber used for production matures be-
tween 80 and 100 years and according to literature even up to 250 years. However, the price between available bamboo boards does not differ largely to timber boards. Currently, a 20mm bamboo board is available on the market costs 87, 35 Euro per square meter. A few interviewees argued that the high price is reasoned by the processing efforts but also the transportation from Asia to Europe. Because of that, some interviewees favored the processing of timber instead of bamboo.

Unlike timber, the majority of interviewees preferred bamboo for its strength and hardwood characteristics. This differed to timber, which has great variance in material characteristics and strengths. Literature and interviews illustrated great knowledge and application around Chinese Moso bamboo with one enterprise using Ethiopian Yoshina Alpina Bamboo. Overall, timber manufacturers made frequent use of the oak, spruce, beech, and maple. Literature also highlighted the excellent usage and application of these species in addition to the ash tree and chestnut. According to literature, these were used because of their unique grain, color variance and strengths characteristics.

4.1.3. Competences

The majority of interviewees included woodworkers that were not involved in the harvest of timber or bamboo. Because of that, they did not need to have particular knowledge regarding the harvest or transportation of timber and bamboo. Therefore, the majority of know-how was related to the actual processing of timber and bamboo. Different knowledge is needed if bamboo culms and timber logs are processed as opposed to timber boards and bamboo panels. Since the majority of interviewees processed either timber boards or bamboo panels, knowledge of processing these seemed more established in practices.

According to one interviewee, to process logs, these need to be sawn into timber boards and then dried. Other interviewees and literature pointed out that this process is usually done in sawmills where timber is processed into boards and then heated in drying chambers. There, its wood moisture content is reduced. Since this process takes more effort, then the processing of timber boards, the majority of woodworkers avoid the processing of logs.

Rarely any of the wood manufacturers process bamboo poles. This is usually done in producer countries such as China. According to literature and the interviews, to produce bamboo panels, bamboo culms are firstly cut into strips, then glued, heated and pressed together. Another option is strand woven bamboo in which the fibers of bamboo are used to produce bamboo panels. During that process, bamboo culms are split into stripes. In the next step, these stripes are crushed into fiber mats. These are laid on top of each other and pressed under high pressure
and temperature while adding resin as binder “(17). As bamboo is heated, it is also treated equally. Bamboo fibers are put into a kiln which reaches between 160-200 degrees Celsius (17). The color of bamboo is then altered according to temperature.

Since the processing of bamboo culms were less favored, most woodworkers processed bamboo boards. The work with bamboo boards was perceived as similar to the work with timber boards. The same type of machinery and knowledge can be used for the processing of both resources. However, it was less illustrated whether the color of bamboo could be altered. Literature and in interviewees showed that the color of wood material could be changed through the application of laze.

The opposite takes place with bamboo. Only one interviewee highlighted that the color could be altered through the use of pigments and strand woven technology. Interviews and desk research illustrated that the color of bamboo could be changed through caramelization. If bamboo is cooked, the natural color is maintained and if bamboo is caramelized, it turns into caramel color. Besides color, strand woven technology can also be used to create different grains and color patterns in bamboo boards. “Different grains and pigments can be used to make bamboo boards look like tropical timber” (15).

While German wood manufacturers perceived that the same knowledge could be used to process bamboo boards like timber boards, they also highlighted disadvantages. Some interviewees mentioned that bamboos’ small fibrous structure makes it more challenging to process. Another interviewee highlighted that the machinery used must be very sharp because of bamboos’ strong mechanical characteristics.

There seemed to be no further differences in the processing of timber and bamboo boards. To process either, they need to be sanded, cut, oiled, and glued into their desired product. Since there are no particular differences, the use of bamboo boards seemed similar favored to timber boards. The only disadvantages for their utilization were the limited grain variance. Bamboos grain is limited as it usually horizontally or vertically glued together. This differs from timber. The vertical sawing of timber logs highlights its natural grain well. “Sawing them horizontally highlights a beautiful grain like a flower” (7).

According to the desk research and the interviews, further knowledge related to the processing of timber and bamboo was related to the wood moisture content of the processed product. Wood products should have a moisture content between 12 and 24 percent. If wood has more or less moisture, it can stretch out, shrink, deteriorate, or crack. While literature did not illustrate the
importance of proper bamboo moisture content, the interviewees mentioned that this also applies to bamboo products. One interviewee even said that not well-dried bamboo is more likely to break and therefore, creates a negative image of bamboo as material by various consumers.
4.1.4. Salience of the elements and their connection

While desk research was useful in providing a preliminary overview of the various elements, the interviews were more useful in illustrating the salience of certain elements and their characteristics. When comparing timber to bamboo practices, it is visible that practices related to the element material were pointed out the most in bamboo manufacturing practices (see Figure 21: Bamboo elements). Overall, less highlighted were practices related to “competences” and the least mentioned were practices related to the element “meaning.” This preliminary observation presumes that the type of material used in production plays a crucial role in the execution of both practices and the preference in the choice of processing certain materials (see Figure 21: Bamboo Elements and figure 22: Timber Elements).

When looking more closely at the most salient elements (those in thick and in the center of the figures), it is possible to illustrate those element characteristics that seem most established in wood manufacturing practices. It is also possible to point out connections between elements and their characteristics. For instance, woodworkers frequently utilize the oak, spruce, beech, and maple, which all have variances in grain and mechanical characteristics. Timber is mostly processed in the form of wood boards. Since wood is mainly processed in the form of boards, most competences needed to process it are the cutting, sawing, sanding,
coating and oiling of the material. Again, the type of wood used likely depends on the grain (see Figure 18: Connection between salient timber elements).

Some salient characteristics of bamboo are also similar to those of timber. For instance, wood-workers mainly process three layered wood panels which are similar to timber boards. Since the grains are different than those of trees, bamboo is appreciated more for other features such as being a sustainable or strength-based material. It seems less appreciated for its look. However, the production process of bamboo panels differs completely to timber boards and because of that, competences seem to center more around the processing of boards instead of their production (see Figure 23: Connection between salient bamboo elements).

The outcomes of the interviews and desk research further illustrate that since the pattern and material differ between bamboo and timber, there are also different feelings associated with it. Timber patterning seems to create “warm feelings” which could be based on the different design options. This differs from bamboo, which is characterized by its interesting nodal character with limited designs.

Further, literature and interviews highlight that the element characteristics of the element “material” differ largely between bamboo and timber. Reasons for that are the different mechanical properties of timber and bamboo. Bamboo has a hollow structure, while timber has a solid structure. Since the structure varies between both resources, the processing of these differs completely. As the processing of bamboo culms into bamboo panels requires much more effort than the processing of logs into timber boards, bamboo appears less attractive to German manufacturers. However, if the industry is in possession of bamboo panels, the same processes involved in the manufacturing of timber products from timber boards can be applied.

Figure 23 (Processes involved in bamboo and timber board production) illustrates the different processes involved in the production of bamboo and timber boards. In order to fabricate a bamboo board, more processes have to be followed. This differs to timber which can be
automatically processed into a timber board. However, if these boards are available, the same techniques and tools can be used for the production of a desired “final product.”

Figure 20: Processes involved in timber and bamboo board production

While boards are available from both resources, their features differ. Timber boards are available in various grains and colors, while bamboo boards are largely available in limited grains and colors. This particular applies to laminated bamboo boards. Strand woven bamboo can have various designs and colors but does not seem to be available to German woodworkers. These usually process laminated bamboo boards that are either horizontally or vertically glued together.
4.1.5. Consumer and producer perspective

The following section discusses the outcomes of the interviews with timber producers and consumers by understanding their perspectives towards bamboo. This section also answers the second sub-questions;

What are views on the integration of bamboo?

a. according to woodworkers

b. according to consumers?

Woodworker perception

The follow-up interviews with timber producers illustrated that the majority of them have experiences in the processing of bamboo. Some of the interviewees appreciate bamboo for its strong characteristics and others appreciate it for its distinct nodal look. Its hardness made it favorable for products such as flooring, furniture and veneers. The interviewees also favored bamboo because it had similar light colors such as the birch and maple.

There were also various timber manufacturers who did not appreciate bamboo. It was less favored because of the limited colors and grains but also its fibrous structure. The limited colors and grains seemed to be the largest barrier among timber manufacturers. They stated that the patterns create a wild and restless look. This would be a barrier for its utilization in projects as customers demand material variety. Other barriers were related to the fact that bamboo strips need to be glued heavily. This was perceived as an ecological disadvantage and made solid timber favored more.

Consumer perception

The outcomes of the timber user interviews illustrate that timber users have different perceptions towards bamboo. The first group appreciates bamboo particular for its look and its stability and material health. Group 2 and Group 3 seemed less knowledgeable about bamboo with Group 4 having clear perceptions regarding the non-suitability for bamboo as a wood product.

(See Table 6: References made about bamboo products)
Summary references made about bamboo products; Buying bamboo because of...

| Group 1 - buying bamboo because of its.. | Group 2 - would buy bamboo if it. | Group 3 – no opinion | Group 4 does not buy it because bamboo is
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Look, stability, strengths, material health</td>
<td>Fits well and looks good</td>
<td>No opinion</td>
<td>An Asian grass, its style does not fit, difficult to wash off, domestic wood preferred</td>
</tr>
</tbody>
</table>

Table 6: References made about bamboo products

Furthermore, the interviews illustrated various purchasing criteria that were applicable across all groups (see Table 7; References made about purchasing decision). One of them is the wood-like character of timber products such as color and stability. This suggests that if bamboo looked like timber, it would be more likely accepted among the four groups. Other features such as functionality and look of the products were also mentioned by all four groups suggesting that if bamboo meets overall German “designs” it could also be accepted.

Summary references made about purchasing decision; to buy a product it needs to have...

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural look, light colors like oak, fit well with other furniture, functionality, quality, stability, lightweight</td>
<td>Look of the product, natural look, stability like solid wood, its functionality, and (light) color. Price/Quality</td>
<td>Wood-like color, functionality, stability and quality, design, fit well together, provide a comfortable feeling</td>
<td>functionality and look, real wood because of material quality and price, sustainability, practicality and wood-like features, dark color, Price/Quality</td>
</tr>
</tbody>
</table>

Table 7: References made about purchasing decision

Interesting is that Group 4, the one group that least favored bamboo, mentioned sustainability and wood-like features. This could suggest that bamboos’ potential or knowledge about the resource seems currently underestimated. Likewise, the interviews illustrate an openness towards the usage of bamboo as long as it meets their design choices, interests and functionality.
4.2 Conclusion

The type of material used in production plays a crucial role in the execution of practices and the preference in the use of certain materials. The study points out that there are distinct differences between the mechanical characteristics of bamboo and timber. Since the processing of bamboo culms requires more extensive processing right after harvest, there seems little potential for the processing of bamboo culms in German wood manufacturing practices. However, the fact that the processing of bamboo culms implies high efforts is inconsequential as German manufacturers mainly process imported bamboo panels, which are similar to timber boards.

A key barrier for the more extensive use of bamboo in German woodworking practices is that bamboo panels are available in limited designs. On the wood market, bamboo panels are currently available in two types of colors and grain. If there was more material variance for bamboo panels, it would likely be used more by woodworkers. However, one unique feature of bamboo is its strengths, which was favored almost among all bamboo and timber manufacturers.

The study also showed that it is possible to produce bamboo boards, such as with strand woven technologies that can create similar timber like surface patterning. It is assumed that if bamboo boards would look more like timber, they could create similar feelings to timber. Therefore, timber boards would likely be more demanded by consumers. Timber, for instance, is related more to warmth, aesthetic and beauty, while bamboo seems to be related more to sustainability, strengths and interesting growth structure.

Tree species such as the oak, beech, spruce, and maple are favored for production. These are appreciated for their characteristics such as strengths and grains such as oak knotty. However, oak knotty is rather expensive with 170 euros per square meter. Reasons for that are its long growth with up to 150 years. With strand woven technologies, various grains and colors could be created. Hence, if the design of bamboo panels is similar to the designs of oak, beech, spruce and maple board, it would be more likely used. In comparison to oak knotty, laminated bamboo only costs 87, 35 Euros per square meter, while being just as favored for its strengths.

Another challenge remains in the fact that bamboo has a fibrous structure and is not available in the form of solid wood. This is a disadvantage for timber manufacturers who prefer the work with solid wood, but also consumers who appreciate material consistency in their products.

Furthermore, the interviews from IKEA illustrate that if bamboo products looked more like timber, they would be more likely accepted by consumers. This particular accounts for consumers who had a negative perception of bamboo due to its “design.” Among these interviewees preference
was given towards the functionality of wood products, the quality and a similar look to timber products. A challenge hereby is that with limited bamboo design options, it is less likely demanded by consumers as well. More variance could change the image of consumers towards bamboo and hence, increase the demand for bamboo products.

The study concludes that there are no fundamental barriers to apply bamboo more widely in wood manufacturing practices. The main barrier seems to be the taste and product design. There seems to be potential to integrate bamboo as another option among the other existing wood types particular due to bamboo’s strengths properties, which make it a useful product such as for flooring and stairs. Until new designs are available for wood manufacturers, bamboo (boards) seem to remain as a niche product in Germany. Figure 21 further summarizes the key opportunities (in green) and barrier (in yellow) for the more extensive use of bamboo in German wood manufacturing practices.

In terms of sustainability, bamboo seems to be a strong potential alternative to tropical timber. It grows quicker and, if the technologies are put into place, can be used for versatile production purposes. Bamboo flooring, for instance, can even look like valuable tropical timber. However, the use of existing bamboo boards in Germany seems more or less a concern of design and less of sustainability. Therefore, a question remains whether knowledge around its benefits should be spread more and whether appearance should remain more important over functionality and sustainability.
4.3 Recommendation for policy, society and further research

German woodworkers referred to bamboo as an interesting material while producer of bamboo products pointed out the potential for bamboo as tropical timber alternative with sustainable characteristics. Among German timber producers and users, product design choices were mentioned more often than the term sustainability. Some interviewees also highlighted that design is more important than sustainability as consumers have to look at the material every day.

Because of that, it is recommended to conduct more research into market diversification and the introduction of more bamboo board variety into retail. While desk research and interviews pointed out that there are technologies that can be used to create variety in the design of bamboo boards, German woodworkers seem to be only able to purchase two types of bamboo panels with limited design choices. If bamboo is demanded more, which could happen through market diversification, more bamboo production could be encouraged in the tropics. This could lead to a greater shift from timber to bamboo and hence, accelerate sustainable development.

In addition, the literature review pointed out an increased demand of the EU Energy Directive for renewable resources. Wood and wood products such as briquettes and pellets account to a total of 45% renewable energy. However, this also bears pressure on tropical timber. Since bamboo can be harvested much quicker while also being known for its high starch content, it should be further promoted as renewable resource alternative as opposed to timber. Therefore, policy research should look into the integration of bamboo as renewable energy alternative to timber.

It is further recommended to conduct more research into consumer perceptions of bamboo and how bamboo could be promoted better. While sustainability seems important to consumers and producers, it appears that the design is more important. In the light of sustainable development, material functionality and sustainability should take up a larger proportion in the choice of material.

4.3. Limitations

Due to the time limitations of the study, it was not possible to interview more bamboo and timber manufacturers. This would have helped in receiving a broader understanding of the market. Another limitation was that the neighboring practices were not analyzed in-depth. These only provided preliminary insight into practices while serving as a crucial comparison. While the application of Social Practice Theory was useful to compare bamboo with timber, it seemed difficult to analyze two different practices in-depth with SPT within the short time frame. Analyzing the market with SPT by focusing on only one practice, could have shed more light on the depth of current practices involving one resource.
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APPENDICES
Appendices

Appendix 1 - List of interviewees

[Only available in the original version which was submitted to my University]
Appendix 2 – Interview Questions

Bamboo Interview Questions

Q1. What type of **expectations** do you have towards the use of bamboo?

Q2. What feelings do you associate to bamboo?

Q3. What type of **ideas** come to your mind when you think of working with bamboo?

Q4: What methods are you using for bamboo preservation?

Q5: How are you **processing** bamboo? (e.g. tools, machinery,…)

Q6: What type of **quality** does bamboo provide for your products?

Q7: What **growth structure** does bamboo have that you are utilising? (e.g. national or non-national bamboo, quickly regenerative or not)

Q8: What type of bamboo product **colour** do you prefer for product production? (per product?)?

Q9: Bamboo has various knots which you can see e.g. in flooring. How do your customers perceive the knots?

Q10: What type of technical characteristics are important for you to consider when working with bamboo? E.g. manufacturing quickly after harvest due to high starch /degradation ability etc.

Q11: What do you perceive as a bamboo advantage in the German market?
Timber Interview Questions

Q1. What type of expectations do you have towards the use of timber?

Q2. What feelings do you associate to timber?

Q3. What type of ideas come to your mind when you think of working with timber?

Q4: How important is the preservation of timber for production?

Q5: How is timber being processed? (Are there differences in terms of types of machinery used for the processing of different wood, slower/quicker wear out,...)

Q7: How do you rate the benefits of timber for production purposes?

Q8: What growth structure does timber have that you are utilising? (e.g. domestic vs non-domestic timber, quickly regenerative or not)

Q10: There are various trees with some trees having more knots than others due to their lengths and tree type. How important are these aspects to you and what type of tree species are you using that fulfils these?

Q11: What form of technical characteristics are important for you to consider when working with timber? (as in timber biological aspects)

Q12: What type of wood colour do you prefer for product production? (per product?)
Appendix 3 – Interview Transcript examples visualizing coding methods

Blue; Material, Orange; Competences, Green; Meaning

Welche Produkte stellen Sie her?
Wir bauen Möbel in aller größten Teils, Schränke, Tische und auch Zimmertüren und Fensterbänke, aber Zimmertüren sind eher selten, wobei nicht mehr so selten, aber schon. So hochwertig ist das dann eher für Möbel, Schränke aus Sperrholz. Möbel hält auch besonders gut für Eigenheimwohnungen oder Häuser.

Was für Holz benutzen Sie am meisten?
Also das aller meiste ist die klassische Sperrholz, die klassische Vollsperrholzplatte und im Massivholzbereich verarbeiten wir am meisten Eiche.

Aber auch andere Holzer wie Fichte oder Ahorn?
Nur Harthölzer wie Ahorn, Buche, Asche. Birke hatten wir gerade.

Und was mögen Sie an der Eiche am meisten?
Dem Kunden und mir gefällt es sehr gut, zum Beispiel in den letzten Jahren haben wir viel Ulme verarbeitet weil das mein absolut lieblingsholz ist. Der Kunde mag daran sehr, das schöne Bild das dabei entsteht, der warme Ton, die Härte, aber das ist eigentlich eher unwichtig.

Sind da besondere Masierungen drin?
Ja, also wir verarbeiteten auch sehr viel Holz was wunderschöne Äste hat, oder Risse, die wir dann entweder so lassen oder dann auch ausfüllen, das hält ne glatte Fläche gibt. Bei Tischen, will ich ja hauptsächlich eine glatte Fläche haben, weil da will ich ja kein Loch drin haben und dann machen wir da halt einen Gruss reih. Auch mit Verfärbungen arbeiten wir. Wenn es etwas hat was normal zu dem Ausschluss von Holz führt, ist es für uns dann etwas, was es besonderes und extra schon macht.

Interessant, weil ich hab gelernt, dass rissiges Holz eher nicht gewollte ist.
Ja, der übliche der mag das nicht, aber ich meine gerade, dass ich das was die anderen nicht wollen, das nehme ich und die Kunden mögen es auch sehr und sind sehr begeistert, wenn wir so etwas verarbeiten.

Verarbeiten Sie das Holz noch oder müssen Sie es dann noch weiter verarbeitet?
Die Sperrholz die bekommen wir ja schon, die werden geschnitten, dann kommen da Fräserungen und Bohrungen rein und Umleimer, muss dann noch gelasen werden. Bei den Platten, ist es halt nur eine Platte, die müssen wir dann je nach dem beschichtet werden, aber halt zuschneiden und fräsen, das müssen wir alles machen. Und beim Massivholz bekommen wir ja neu Stammware, die sind etwas länger, die müssen wir dann aufbrechen und dann wieder verleimen und mal müssen sie gehobelt werden und zurechtschneiden und selbst bauen. Also bekommen wir immer roh unbehandelt.

Müssen Sie das noch trocknen oder kommt das getrocknet?
Das ist alles fertig getrocknet.

Ist es dann auch nicht anfällig für Risse etc.?
Ich bin der Meinung, dass wir arbeiten eh nur im Innenbereich, da gibt es keine Gefahr von Pilzen oder nur sehr geringe, wenn man zum Beispiel eine Arbeitsplatte für die Spiele einbauen muss, dass da möglichst keine Feuchtigkeit drunter ist, damit es nicht schimmelt, aber im Prinzip ist es überhaupt sehr wichtig, dass man darauf achtet, dass der konstruktive Holzschnitt stimmt, also das die Feuchtigkeit, die eindringt, die auf jeden Fall eindringt, das ist nicht zu verhindern, dass Feuchtigkeit eindringt. Ich muss nur auch so schnell wieder wegtrocknen können, bevor wieder neue Feuchtigkeit rein kann. Muss halt sich immer ausgleichen können im Klima und wenn das nicht gegeben ist, wenn man Holz im Aussenbereich lackiert hat es keine Möglichkeit mehr auszudampfen. Durch irgendwelche Risse oder Fugen, kann das Wasser halt entweichen, aber es hat keine Möglichkeit mehr zu entweichen, weil es verteilt sich ja im ganzen Holz und es müsste ja über die ganze Fläche verdampfen können und das ist ja nicht, wenn es wasserdicht lackiert ist, aber es ist halt nicht immer so, weil ja doch irgendwelche Risse immer drin sind, weil der Lack halt an manche Stellen nicht kommt. Das wichtigste ist einfach, dass man sehen muss, dass Wasser wenn es rein kommt auch einfach rauskommt.

- Wenn man Holz in einem anderen Land benutzt will, muss man vut auch was auf die Luftfeuchte achten?

Ja, aber nicht so sehr. Muss man halt so bauen, dass wenig Feuchtigkeit reinkommt, aber die Restfeuchte die auch wieder raus kommt. Das staut sich halt und Stau und Nässe führt dann immer zu nichts gutem.

- Wegen dem Holz, haben Sie da genug oder ist die Nachfrage größer?

Ne, Mangel an Holz haben wir nie. Wir kaufen es nur wenn wir es brauchen und auch nur die Menge die wir brauchen.

- Haben Sie schon mal tropisches Holz gekauft

Fast nur europäisches Holz, ob es aus Deutschland kommt kann ich nicht sagen, kann auch aus Russland oder sonst wo in Europa kaufen.

- Wieso kein tropisches Holz?

Die Wege sollten kurz sein, die die Ware zurücklegt. Tropenholz gefällt mir auch nicht so gut und dann kommt ja auch die Frage, wo das Holz herkommt, ist es nachhaltig bewirtschaftet also von den Wäldern her. Bei dem Europäischen kann ich ausschließen dass es Raubbau ist, weil die Flächen so klein sind. Die haben da dann kein Interesse dran. Es gibt auch keinen Frage, weiß nicht wie es wäre wenn jeder 2ter Kunde nach Mahagoni nachfragen, die wollen auch alle was ich will praktischerweise.

- Hatten Sie schon mal überlegt Bambus ins Sortiment zu nehmen?

Was wir manchmal verarbeiten sind BAMUSplatten, das finde ich auch ganz attraktiv.

- Warum benutzen sie dann die platten davon?

Das ist eine rein optische Frage, weil es gute Eigenschaften hat und Feuchtigkeitsbeständigkeit oder so was, aber es ist nicht so relevant. Ich finde es einfach schön, der einzelne Grund eigentlich und es hört sich sehr schamant an, es hat so einen guten Beigeschmack sage ich mal :D

- Und die Farbe ist so ähnlich wie bei der Eiche dann?
JA genau, ist ein bisschen beller, so Cognac ist ein bisschen eingefärbt, nicht gebeizt, aber so etwas brauntoniger, eher der Eiche entsprechen während die hellen bambusplatten eher einer Birke oder dem Ahorn entsprechen.

- Da gibt es nur die zwei Farbanteile?

Ist die Verarbeitung ist gleich, aber ich habe auch keinen genauen Vergleich. Aber wir verarbeiten jetzt tauch manchmal Beton und da sind die Werkzeuge sehr schnell abgeschliffen, aber bei Holz kann ich das nicht sagen. Also das ist jetzt nicht ganz besonders. Da gibt es Hölzer, die auch wesentlich härter sind als Bambus.

- Bei der Verarbeitung gibt es Nachteile?

### Appendix 4 – Example to illustrate the summaries of the interviews per elements

This table illustrates the summaries of the bamboo interviews. These consists of short sentences or bullet points. Each row relates to the statements made by one interviewee and is numbered in accordance with the order of the interviews conducted (see red circle). To relate the information cited in the section “result interviews”, each number and content is corresponding to an interviewee (See Appendix 1; List of interviewees). The rows list each element that was correspondingly summarised per interviewee (see blue circles).

In total, three tables were created; interviews with timber manufacturers, interviews with bamboo manufacturers and the follow-up interviews with timber manufacturers.
Appendix 5- Transcript IKEA interviews

Questions;

- Questions 1. Was ist Ihnen beim Kauf von Holzmöbeln am wichtigsten? (What is most important to you when buying wood furniture?)

- Question 2: Was halten Sie von dem Kauf von Bambusmöbeln? (What do you think about buying bamboo furniture?)

Responses;

Customer 1.

1. Real wood, natural look, light is better. The colour should be in fashion, preferably light material like (Eiche)
   2. Bamboo is also cool. My desk is made of bamboo

Customer 2

1. Colour is important. I like white colour and real wood
   2. No perception about bamboo

Customer 3

1. Functionality, real wood
   2. No opinion about bamboo

Customer 4

1. Should fit well to the other furniture, needs to fit my budget
   2. Bamboo is also totally okay

Customer 5

1. Needs to be stable, I don’t like the material which is pressed together, because I have kids and sometimes things break or a water glass falls over, and then the interior gets “swelled up”, and that’s bad. So the quality is important and of course the look. Cheap flooring I don’t like.
   2. No real opinion about bamboo
Customer 6

1. Should be easily built together, good quality, stable, great material health like no bad glue. I like real wood, but it is heavy so it should be sold in smaller units so that I can carry it.
2. I like bamboo because it is light, but because it is light it is not useful for the garden because if the wind blows, my furniture blows away. For the inside I think it is good. It depends really on the product and where to use it.

Customer 7 + Customer 8

1. Should not break easily. Quality and preferably dark material
2. No opinion about bamboo

Customer 9

1. Functionality, particular the look.
2. It should just fit, so it does not matter if it is bamboo

Customer 10

1. Preferably real wood because of the quality. But the look is more important.
2. If bamboo also looks good, I would not mind buying bamboo products.

Customer 11

1. It should be functional and sustainable
2. Don’t like bamboo

Customer 12

1. Quality
2. No opinion

Customer 13

1. I like natural looks, like light wood, does not need to be completely wood and doesn’t have to be real wood
2. I don’t know anything about bamboo

Customer 14

1. It needs to be cheap
2. Bamboo only belongs to my cooking pot
Customer 15

1. It should be sustainable and stable like (Massivholz)
2. I didn't know you could build furniture with bamboo, interesting

Customer 16

1. Functionality and design are very important to me.
2. I have no clue about bamboo

Customer 17

1. Depends on the purpose of the product
2. I like bamboo because it is more hygienic than other materials

Customer 18

1. Quality and stability are important
2. I like bamboo because it is very stable

Customer 19

1. Please, only real wood and no Sauerkraut. It just needs to fit.
2. If bamboo fits in, why not

Customer 20

1. Price/Quality ratio needs to fit, and I like timeless design
2. I have some bamboo products, but I don't know why. Maybe because they just fall into my hands when buying

Customer 21

1. Needs to be practical. I like real wood the most if you can pay for it, of course.
2. When I was in my youth, I really liked bamboo; now, it does not suit my taste anymore.

Customer 22

1. Colour is important and functionality
2. I wouldn't mind buying bamboo products as long as they suit into everything else

Customer 23

1. Massivholz, easy to refurbish, so they last longer and it is easier to move with them. With other material they break, and you can't keep them long.
2. I perceive the same with bamboo. I have bamboo furniture in my bathroom and it’s easy to refurbish.

Customer 24

1. I prefer light wood and real wood because it does not break easily.
2. I would also buy bamboo; I think my brother actually has a bamboo table from IKEA.

Customer 25

1. Prefer real natural wood
2. I think it is nice, but it’s a grass, but it is very hard grass.

Customer 26

1. FOR sure I prefer real wood
2. Please, no bamboo, it does not belong to here, much more (Buche oder Eich), Bamboo...
   Bamboo is more for Asia, not our region. It does not fit to here.

Customer 27

1. Functionality, colour doesn’t really matter
2. Bamboo furniture does not fit into our home.

Customer 28

1. Masssivholz, functionality
2. No bamboo, it does not fit into our home. Its not our style.

Customer 29 + Customer 30

1. For us only the look is important
2. It can be bamboo as long as it looks good.

Customer 31

1. Quality for sure
2. We like bamboo furniture 😊

Customer 32

1. Functionality just needs to fit everything else.
2. No opinion about bamboo
Customer 33

1. Functionality, easy to fit together
2. No opinion about bamboo

Customer 34

1. Colour, comfortability
2. No opinion about bamboo

Customer 35

1. Quality
2. No bamboo, because it does not fit our style

Customer 36

1. Price/quality needs to fit, preferably certified like FSC
2. Better no bamboo because it is difficult to wash, I have some products like bamboo spoons but better no furniture.

Customer 37

1. The look is very important
2. Bamboo okay, as long as it fits in

Customer 38

1. Functionality
2. Bamboo okay, as long as it fits in with the rest

Customer 39

1. Should be practical and real wood, sustainable, so I buy only old furniture
2. Bamboo... I don't know. It's not my thing

Customer 40

1. Should be cheap and easy to assembly.
2. Bamboo furniture, yes of course.
Colour Codes:

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<th>Meaning</th>
<th>Occurrence</th>
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</tr>
<tr>
<td>Dark Green</td>
<td>Likely to purchase bamboo with conditions</td>
<td>10</td>
</tr>
<tr>
<td>Purple</td>
<td>Against bamboo material</td>
<td>9</td>
</tr>
<tr>
<td>Grey</td>
<td>No opinion</td>
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**Total;**

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