AN ABSTRACT OF THE THESIS OF

Gabriel Schwarzmann for the degree of Master of Science in Wood Science presented on July 24, 2017.

Title: Establishing New Markets for CLT – Lessons Learned

Abstract approved:

______________________________________________________________________________

Eric Hansen

CLT is becoming global. New countries and regions increasingly realize the potential of what can be done with CLT. As a result, new markets are forming and new companies are entering the industry. Every new region or country that opens its doors to CLT has its own challenges and opportunities. However, there is the unique opportunity to learn from the existing Original Market in Europe and the companies that have been successful there for many years. Especially the German-speaking alpine region was, and still is, the cradle of CLT innovation. Therefore, this research, using qualitative methods, analyzed market characteristics and business models of this region. Lessons learned over the years were identified such as the importance of high-level timber education, the role of designing for building services, hype versus reality with respect to tall wood buildings and how careful design processes are key to competitiveness of CLT buildings. Threats and challenges in the North American CLT market were also identified there. The combined findings give an enhanced understanding of how the implementation of CLT in North America, as an example of a new global market, can be fostered.
Master of Science thesis of Gabriel Schwarzmann presented on July 24, 2017

APPROVED:

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Dean of the Graduate School

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Gabriel Schwarzmann, Author
ACKNOWLEDGEMENTS

First of all, I want to thank Eric Hansen, my major advisor at Oregon State University and Günter Berger my co-advisor at Salzburg University of Applied Sciences, for the continuous advice and encouragement they have given me. In addition to that, I want to especially express my gratitude towards all the support I have received from Dr. Kaichang Li, who provided my assistantship. Likewise, I am very thankful to the Tall Wood Design Institute. They provided funding for this research and therefore made the extensive data collection possible. Also, a great help and motivation, were my friends and fellow students at the department of Wood Science and beyond. I feel very lucky, to have studied with some incredible individuals. Besides university, I am genuinely thankful to have a loving family that, no matter what, wholeheartedly supports me and my dreams. Lastly, I want to dedicate this work to Clifton Westin and Kate Eagle Westin, who grounded me in this foreign culture. With them I have a home, in Corvallis, Oregon, or wherever they may be.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I - INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>a - OBJECTIVES</td>
<td>4</td>
</tr>
<tr>
<td>II - BACKGROUND</td>
<td>5</td>
</tr>
<tr>
<td>a - THE MATERIAL CLT</td>
<td>5</td>
</tr>
<tr>
<td>i - Production</td>
<td>6</td>
</tr>
<tr>
<td>ii - Planning &amp; Prefabrication</td>
<td>6</td>
</tr>
<tr>
<td>iii - Environmental Aspects</td>
<td>8</td>
</tr>
<tr>
<td>b - RELATED RESEARCH</td>
<td>8</td>
</tr>
<tr>
<td>III - THEORETICAL BACKGROUND</td>
<td>11</td>
</tr>
<tr>
<td>a - MARKET VARIABLES</td>
<td>11</td>
</tr>
<tr>
<td>i - Political/Legal</td>
<td>13</td>
</tr>
<tr>
<td>ii - Economic</td>
<td>13</td>
</tr>
<tr>
<td>iii - Social</td>
<td>14</td>
</tr>
<tr>
<td>iv - Technological</td>
<td>14</td>
</tr>
<tr>
<td>v - Demand</td>
<td>14</td>
</tr>
<tr>
<td>vi - Supply</td>
<td>15</td>
</tr>
<tr>
<td>vii - Competition</td>
<td>15</td>
</tr>
<tr>
<td>viii - Distribution</td>
<td>15</td>
</tr>
<tr>
<td>ix - Customers</td>
<td>16</td>
</tr>
<tr>
<td>x - Existing Structures in Market</td>
<td>16</td>
</tr>
<tr>
<td>b - BUSINESS MODEL VARIABLES</td>
<td>16</td>
</tr>
<tr>
<td>i - Nine Building Blocks of Osterwalder &amp; Pigneur</td>
<td>18</td>
</tr>
<tr>
<td>ii - Customer Segments</td>
<td>19</td>
</tr>
<tr>
<td>iii - Value Proposition</td>
<td>19</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS (Continued)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>iv - Channels</td>
<td>20</td>
</tr>
<tr>
<td>v - Customer Relationships</td>
<td>20</td>
</tr>
<tr>
<td>vi - Revenue Streams</td>
<td>21</td>
</tr>
<tr>
<td>vii - Key Resources</td>
<td>21</td>
</tr>
<tr>
<td>viii - Key Activities</td>
<td>22</td>
</tr>
<tr>
<td>ix - Key Partnerships</td>
<td>22</td>
</tr>
<tr>
<td>x - Cost Structure</td>
<td>23</td>
</tr>
<tr>
<td>xi - Strategies</td>
<td>23</td>
</tr>
<tr>
<td>c - SWOT ANALYSIS</td>
<td>24</td>
</tr>
<tr>
<td>IV - METHODS</td>
<td>25</td>
</tr>
<tr>
<td>a - CONDUCTING CASE STUDIES</td>
<td>25</td>
</tr>
<tr>
<td>i - Types of Case Studies</td>
<td>26</td>
</tr>
<tr>
<td>ii - Validity of Case Studies</td>
<td>27</td>
</tr>
<tr>
<td>iii - Generalizability of Case Studies</td>
<td>29</td>
</tr>
<tr>
<td>iv - Single-p vs. multiple-case studies</td>
<td>30</td>
</tr>
<tr>
<td>v - Data collection for Case Studies</td>
<td>31</td>
</tr>
<tr>
<td>vi - Analysis of case studies</td>
<td>33</td>
</tr>
<tr>
<td>b - RESEARCH FRAMEWORK</td>
<td>35</td>
</tr>
<tr>
<td>i - Structure for Data Collection</td>
<td>36</td>
</tr>
<tr>
<td>ii - Structure of Results</td>
<td>37</td>
</tr>
<tr>
<td>c - SAMPLING</td>
<td>38</td>
</tr>
<tr>
<td>i - Markets</td>
<td>39</td>
</tr>
<tr>
<td>ii - Selection of experts and manufacturers</td>
<td>40</td>
</tr>
<tr>
<td>d - DATA COLLECTION THROUGH SECONDARY RESEARCH</td>
<td>43</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS (Continued)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>i - Web search</td>
<td>43</td>
</tr>
<tr>
<td>ii - Data bases</td>
<td>43</td>
</tr>
<tr>
<td>iii - Non-academic publications</td>
<td>43</td>
</tr>
<tr>
<td>iv - Papers &amp; studies</td>
<td>44</td>
</tr>
<tr>
<td>v - Books</td>
<td>44</td>
</tr>
<tr>
<td>e - DATA COLLECTION THROUGH PERSONAL INTERVIEWS</td>
<td>44</td>
</tr>
<tr>
<td>i - Personal interviewing in context</td>
<td>45</td>
</tr>
<tr>
<td>ii - Developing questions</td>
<td>45</td>
</tr>
<tr>
<td>iii - Structuring of interviews</td>
<td>45</td>
</tr>
<tr>
<td>iv - Probing</td>
<td>47</td>
</tr>
<tr>
<td>v - Ethics of interviewing</td>
<td>48</td>
</tr>
<tr>
<td>vi - Transcribing &amp; Note Taking</td>
<td>49</td>
</tr>
<tr>
<td>f - OBSERVATIONS</td>
<td>52</td>
</tr>
<tr>
<td>g - DATA ANALYSIS TECHNIQUES</td>
<td>52</td>
</tr>
<tr>
<td>h - RELIABILITY &amp; VALIDITY</td>
<td>54</td>
</tr>
<tr>
<td>i - MINIMIZING LANGUAGE BIAS</td>
<td>55</td>
</tr>
<tr>
<td>V - RESULTS</td>
<td>57</td>
</tr>
<tr>
<td>a - THE HISTORY OF CLT</td>
<td>57</td>
</tr>
<tr>
<td>b - MARKET AND BUSINESS CHARACTERISTICS</td>
<td>59</td>
</tr>
<tr>
<td>i - General comparison</td>
<td>59</td>
</tr>
<tr>
<td>ii - Opportunities for CLT in OM and NA</td>
<td>62</td>
</tr>
<tr>
<td>iii - Threats for CLT in OM and NA</td>
<td>66</td>
</tr>
<tr>
<td>iv - Strengths of CLT manufacturers in OM and NA</td>
<td>71</td>
</tr>
<tr>
<td>v - Weaknesses of CLT manufacturers in OM and NA</td>
<td>73</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS (Continued)

Page

C - LESSONS LEARNED....................................................................................................... 75
   i - Wood Education ........................................................................................................... 75
   ii - Holistic Building Concept ........................................................................................ 78
   iii - Holistic Design......................................................................................................... 79
   iv - Wood & Water ........................................................................................................... 80
   v - Building Services ...................................................................................................... 81
   vi - Tall Wood Illusion .................................................................................................... 83
   vii - Hybrid Systems ...................................................................................................... 85
   viii - Prefabrication and Automatization ..................................................................... 87
   ix - Care and Precision .................................................................................................... 89
   x - Establishing New Production Facilities .................................................................. 90
   xi - Find Market Entry Points ....................................................................................... 91
   xii - Competitiveness of CLT ....................................................................................... 92
   xiii - R&D is needed ....................................................................................................... 94
   xiv - Efficient Use of Wood ............................................................................................ 95

d - CLT FORECAST FOR NORTH AMERICA ................................................................. 96

VI - CONCLUSION ............................................................................................................. 99
VII - FUTURE RESEARCH ................................................................................................. 102
VIII - BIBLIOGRAPHY ........................................................................................................ 104
IX - APPENDIX ................................................................................................................ 108
1 - THESIS OVERVIEW .................................................................................................... 108
2 - CONFIDENTIALITY & RECORDING ......................................................................... 108
3 - INTERVIEW QUESTIONS ............................................................................................ 109
   3.2 - Questions for Experts in Original Market [German] .............................................. 110
### TABLE OF CONTENTS (Continued)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3 - Questions for Experts in New North America [English]</td>
<td>111</td>
</tr>
<tr>
<td>3.4 - Questions for Manufacturers in Both Markets [English]</td>
<td>112</td>
</tr>
<tr>
<td>3.5 - Questions for Manufacturers in Both Markets [German]</td>
<td>113</td>
</tr>
<tr>
<td><strong>4 - DATA COLLECTION FRAMEWORKS</strong></td>
<td>114</td>
</tr>
<tr>
<td>4.1 - Research Framework</td>
<td>114</td>
</tr>
<tr>
<td>4.2 - Probing Categories for Expert Interviews [English]</td>
<td>115</td>
</tr>
<tr>
<td>4.3 - Probing Categories for Expert Interviews [German]</td>
<td>116</td>
</tr>
<tr>
<td>4.4 - Probing Categories for Manufacturer Interviews [English]</td>
<td>117</td>
</tr>
<tr>
<td>4.5 - Probing Categories for Manufacturer Interviews [German]</td>
<td>118</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1: The tree of the CLT industry</td>
<td>3</td>
</tr>
<tr>
<td>Figure 2: Cross Laminated Timber Panel by Dataholz (2012)</td>
<td>5</td>
</tr>
<tr>
<td>Figure 3: Theoretical Framework - Market Variables</td>
<td>11</td>
</tr>
<tr>
<td>Figure 4: The Information Environment Model (Hansen &amp; Juslin)</td>
<td>12</td>
</tr>
<tr>
<td>Figure 5: Theoretical Framework – Business Models</td>
<td>17</td>
</tr>
<tr>
<td>Figure 6: Theoretical Framework</td>
<td>35</td>
</tr>
<tr>
<td>Figure 7: Structure for Data Collection</td>
<td>36</td>
</tr>
<tr>
<td>Figure 8: Structure of Results</td>
<td>37</td>
</tr>
<tr>
<td>Figure 9: The Original Market of CLT</td>
<td>40</td>
</tr>
<tr>
<td>Figure 10: Informant geographical location and type</td>
<td>42</td>
</tr>
<tr>
<td>Figure 11: TIFI approach adapted from Clausen (2012)</td>
<td>51</td>
</tr>
<tr>
<td>Figure 12: Significance factors</td>
<td>53</td>
</tr>
<tr>
<td>Figure 13: Results stage 1: SWOT analysis</td>
<td>59</td>
</tr>
<tr>
<td>Figure 14: Results stage 2: Lessons Learned</td>
<td>75</td>
</tr>
</tbody>
</table>
I - INTRODUCTION

Wood has a very long history in building construction and architecture. Trees always provided a material that is abundant and comparably easy to use with a minimum processing and manufacturing effort. Early manmade shelters and roofing structures were tents made out of wooden posts that supported animal skins. Later, actual housing units had simple solid wall and roof structures which were supported by wooden components (Hansen & Berg, 1971). As the use of wood in architecture evolved, the amount of processing also increased. More sophisticated architectural shapes and designs created a need for new wood materials. Lumber and beams were used, and various shapes and dimensions were produced from one single tree. For a long time, sawn timber in all its diversity was the only available structural wood products.

With the invention of wood adhesives that were strong enough for structural applications new products were invented, such as large glulam beams and columns that were made of small dimension lumber. The most revolutionary invention was the ability to make structural panels out of wood. Plywood was one of the first widely used wood panels, especially in timber frame construction and in the 1880s OSB (Oriented Strand Board) entered the construction market (Bowyer, et al., 2007). However, all those panels were limited in thicknesses and mainly used as sheeting and cladding material, where they could only be used for reinforcement to absorb horizontal forces in a building. They still were no real vertical load bearing members.

With the invention of CLT in the early 1990s, this changed. With its unique nature CLT is a massive structural wood product that can take loads in more than one direction, while being strong and stiff enough to function as only structural member in a wall, ceiling or roof. This development first encountered some skepticism because of its high use of the raw material
wood, but shortly people increasingly understood the full potential of CLT as a building system. It took 20 years for CLT to establish itself as a viable alternative to other conventional massive building systems. A new market was born.

The forming of the initial market of CLT in the German-speaking alpine region of Europe was a complex interplay of individuals, companies, decisions, ideas, strengths, and also weaknesses. The more people got in touch with this new construction technique, the wider its influence grew. Slowly, other areas of Europe became involved and the bigger European market opened up. Companies expanded their operations and new companies emerged. Some also disappeared. Today, the CLT industry especially in the German-speaking alpine region of Europe is a dynamic and still rapidly growing market with more than 2 decades of history. Opportunities were exploited and challenges were overcome. There is a great amount of knowledge and experience that developed over the years.

The success story of CLT, however, did not stop at European borders. New countries and regions started to show increasing interest in the product. Some international architects and building planners consider CLT as an alternative and sometimes even order from Europe. This way, European companies gained customers all over the world, and the word CLT started spreading to new markets. With this growth in awareness, demand also started to grow and new CLT production lines started to emerge outside of Europe.

Altogether, the CLT industry is at a very interesting stage right now. The graphic on the next page, shows a comparison of the industry with the physiology of a tree. The old, well established market in Europe acts like the roots and trunk. History and continuous innovation build a reliable and solid foundation. Now some new markets are emerging outside of Europe and the tree has started to get its first branches and twigs. Some of them
are thicker and longer already and some are still very small. These new markets are now trying to grow and build up their own structure and body. A main part of that are new building projects in CLT, which are of essential importance for the acceptance and adoption of CLT as a valid alternative in the marketplace. Early birds and entrepreneurs establish new companies and have to go through the whole process of dealing with the challenges new market implementations bring with them. In order to address exactly this topic, this thesis attempts to strengthen the connection between the new globally growing branches and the old European trunk, so that new markets can learn from the success of the Original Market and avoid making the same mistakes again. Fewer mistakes furthermore lead to lesser wasted time and money and to a following faster success.

To sum it up, this research attempts to provide fertilizer for the new branches, so that they can grow and flourish fast and healthy. A strong and energetic crown is essential to the vigor and growth of the whole CLT tree. Within this thesis exclusively North America, especially Canada and the US are looked at as an example of a new market for CLT.
OBJECTIVES

The main objective is to develop a good understanding of how new markets for CLT, especially the North American market, develop and how this development can be fostered. Ideas and suggestion for doing so are on one hand based on information directly from new markets and the companies within and on the other hand on specific lessons that can be learned from the Original Market in the German-speaking alpine region of Europe. Opportunities and threats in individual markets and strengths and weaknesses of companies are described. Further the relations between those aspects are analyzed to obtain a complete and coherent understanding.

The following main questions are asked and sought to be answered on the coming pages:

- How can challenges and threats be dealt with, and opportunities and drivers be used to foster the implementation of CLT in the new North American market?
- How can North America as new market learn from the market development of CLT in the Original Market of the German-speaking alpine region of Europe?
II - BACKGROUND

a - THE MATERIAL CLT

Cross laminated timber (CLT) is a massive wood product that uses boards to make large-scale structural wood panels. The individual boards are arranged side-by-side in layers, whereas every other layer is turned 90 degrees. An odd number of layers is needed, with 3, 5 and 7 being common (Brandner, 2013, p. 1). Most companies use adhesives to connect the separate components to a single load bearing panel, but different types of mechanical fasteners, like wooden dowels, nails and screws are used also by some companies. Aluminum pins especially have gained popularity, because they are soft enough to be processed on a CNC machine. With respect to the adhesive bonded panels, polyurethane (PUR) glues are most widely used followed by melamine urea-formaldehyde systems (MUF) (Muszynski, et al., 2017). Following picture shows a panel of CLT:

![Cross Laminated Timber Panel by Dataholz (2012)](image)

*Figure 2: Cross Laminated Timber Panel by Dataholz (2012)*
i - Production

According to Brandner (2013), there are 6 main steps in the production of CLT. Number 1 is the grading of already dried boards. Following this, unwanted defects are cut out and the remaining segments are reattached to endless lamellae using finger joints. As a third step, those long lamellae are cut to the lengths which are later needed for the horizontal and vertical layers of the CLT panel. Then some companies make single-layered panels, by gluing the edges of the boards, and other companies directly go to step 5 which is the assembly of all boards to cross layers and to the final CLT. As a last production step, those raw panels are cut and customized to meet the individual customer’s needs.

ii - Planning & Prefabrication

Due to its cross layers CLT can take forces from all directions and does not need additional reinforcement. Therefore, it can be used to build full wall, ceiling and roof elements. Putting them together, an entire static structure of a house can be made of CLT. Hence the planning process is very important. Windows and doors are usually cut out of a solid panel as needed. This makes every single panel element a unique and custom-made product and gives the architect and planner a high degree of freedom in their planning and creativity. Also, the connections between the individual panels must be planned carefully so that the assembly of a structure on site can be done easily, quickly and securely. Compared to other construction techniques, CLT buildings can be built in a very short amount of time, which brings a considerable financial advantage, as well as in terms of vulnerability to bad weather conditions. Stauder (2013) says that in some cases the time needed to build one level of a multi-story building can be as little as one week.
There is a great variety of different ways and techniques on how to connect separate CLT panels to each other in an architectural structure. Generally, dowel-type steel fasteners and steel plate moldings are used. Former can be nails, screws, rod dowels and fitted bolts. Screws are gaining popularity, because if used at an angle, they are stressed parallel to the screw axis where they have a high load bearing capacity and are therefore functioning very efficiently (Schiermeyer, 2012).

In most cases, all the elements of a CLT building are prefabricated in the production facility. All panels are precisely cut to their final dimensions, so that they will perfectly fit together. If necessary, special folds, grooves and recesses are made, which are needed for certain types of fasteners. Further, all openings are cut into the panels according to the architectural design and often also channels for building services like electrical wiring and water piping are introduced. If a high degree of prefabrication is pursued, in some cases even insulation layers, vapor barriers and a final cladding can be premounted. Those prefabricated building elements are then transported to the building site by truck. Transportation regulations are often the limiting factors for the dimensions of the individual components and therefore should be known prior to the planning phase.

Once all elements arrive on the construction site, the next crucial step of building with CLT is to assemble all the separate parts. Since they usually are of large scale, they need to be handled by crane. Usually 1 or 2 cranes are needed, depending on the size of a building site. Some of the trucks used for transportation have integrated cranes, but often additional ones are used. A small team of trained professionals is now needed to accurately put all pieces together. Hereby it is very important to have a clear and direct communication with the planner, to ensure that the whole construction system is assembled correctly using the correct types of connectors. This is crucial, since the static integrity of a structure is largely
depending on those details. Therefore, the planner must provide easily understandable and well-defined documentation of the whole building system prior to the time of assembly.

### iii - Environmental Aspects

As CLT is made of wood, it is almost entirely based on renewable resources. Compared to other massive building materials like concrete, steel or masonry, this is very unique. In addition to that, CLT needs less energy in production and construction, than competing products. Thinking further, a CLT building can also be disassembled very easily and the material itself can be either recycled, used as combustible or even be decomposed. Another point that is often mentioned in relation to CLT is carbon sequestration or carbon storage. Trees use carbon from the atmosphere during their growth and build it into their cellular structure. Once they are harvested and used as wood in a CLT building, all this carbon is stored in the building structure. So, the more buildings are built with CLT, the more carbon is withdrawn from the atmosphere, which has a positive effect on the reduction of greenhouse gases.

### b - RELATED RESEARCH

A great amount of CLT research has been done around the technical development of the material itself, as well as its production and use within a building system. In contrast, the extent of existing market related research is comparably small. However, there are a number of studies, institutions and individuals that do focus on market and industry aspects of CLT. This section tries to provide an overview on what has been done in that regards.
In academia, Mallo & Espinosa (2015) at University of Minnesota (UMN) are talking about: ‘Awareness, perceptions and willingness to adopt Cross-Laminated Timber by the architecture community in the United States’. Within this study, also some opportunities and challenges for CLT in the US are identified. An earlier study, also by Mallo & Espinoza (2014) focuses especially on potential barriers for the adoption of CLT in the US and aims at providing an: ‘Outlook for Cross-Laminated Timber in the United States’. Further, Pei et al. (2016) published a conference paper from WCTE 2016, that shows; ‘An Overview of CLT Research and Implementation in North America’. As the name implies, it gives an extensive overview of the current stage of the North American CLT market. It also includes some ‘Identified Challenges’. Another more global study, at Oregon State University, has been looking at: ‘Insights into the Global Cross-Laminated Timber Industry’ (Muszynski, et al., 2017), which focuses greatly on industry capabilities and manufacturer characteristics. In addition to that, Schickhofer at Graz University of Technology released several state-of-the art analyses and future development estimations for the CLT industry through various different outlets like publications, conference papers, presentations (Schickhofer, et al. 2017) and trade journal articles (Plackner, 2015).

Also, some non-academic research has been closely following the development of the global and regional CLT market and industry. The Austrian trade journal Holzkurier for example, annually publishes a special edition magazine called ‘BSP Special’ (BSP is the German abbreviation for CLT). It includes a comprehensive map of CLT manufacturers and also addresses current matters of concern and excitement, within the Austrian, but also global CLT markets. FPInnovations is another contributor to market related knowledge in North America, with ‘Cross Laminated Timber: a Primer’ by Crespell (2010) and ‘Cross Laminated Timber: The Market Opportunities in North America’ by Toosi (2011) as some of their documents. The by far most elaborate market study on CLT however, was recently
done by the North American consulting company *Forest Economic Advisors* (FEA). This high-priced: ‘*Global Outlook for Engineered Lumber Products, 2010-2021*’ contains very detailed information on a number of engineered wood products, including CLT. Highly analytical, the past 7 years of global development are analyzed and a comprehensive and detailed assessment for the next 4 years is provided.

Besides that, one aspect is represented in research very scarcely, being lesson that can be learned from the historic development of CLT. Schickhofer et al. (2017) show a short list of ‘*reasons for the success in Austria*’. These seven bullet points give information on what factors helped CLT to grow, especially in Austria, and focus mostly on existing qualities of the Austrian CLT market, industry and academia. Stauder (2013) on the other hand, published: ‘*CLT - An analysis of the Austrian industry and ideas for fostering its development in America*’, which was conducted in cooperation with the Marshall Plan Foundation, at the Salzburg University of Applies Sciences in Kuchl, Austria. He mainly focused on documenting the Austrian CLT industry as a foundation to find out how the equivalent industry in the US could be fostered.

Considering the described research landscape, this research is contributing to the bigger picture by strengthening the lessons learned aspect, with an especial focus on the North American market. For doing so, also market characteristics are collected, so that the discovered lessons learned can be put into the context of the North American market.
III - THEORETICAL BACKGROUND

a - MARKET VARIABLES

In order to get a comprehensive overview of different CLT markets, this thesis relies on a theoretical framework of categories. To make sure, all important market aspects are considered, they are based on theoretical models that are found in literature. All of them are further explained on the following pages. Following figure shows the categories used:

![Market Variables Diagram]

*Figure 3: Theoretical Framework - Market Variables*
In literature, there are a few existing theoretical frameworks that help to describe a marketplace. One of the most common ones is the so-called PEST analysis, which is an abbreviation for political, economic, social and technological. Together, they can describe the external information of a company’s marketing planning, and describe important external influences on a company. Some even call it PESTEL and add the two variables environmental and legal (Yüksel, 2012).

Hansen and Juslin (2011) adapted this concept specifically to forest products marketing and created a structure to guide the information gathering process of marketing planning called: The Information Environment Model. Following illustration shows this model.

Figure 4: The Information Environment Model (Hansen & Juslin)
This structure divides all aspects that influence a company into two main areas, called the \textit{macro environment} and the \textit{micro environment}. The \textit{macro environment} includes \textit{Demand}, \textit{Supply} and \textit{Other macro environment}, which are usually worked with in higher level marketing. The \textit{micro environment} on the other hand, contains aspects that describe the behaviors of customers, competitors and systems of distribution (Hansen & Juslin, 2011).

This research will make use of the categorizations of the \textit{PEST analysis}, with the additions of the \textit{Information Environment Model} to guide the process of drawing a comprehensive understanding of the CLT industry. Additionally, one more category is introduced, called \textit{Existing CLT structures}, which is thought to be of particular importance within the current global CLT industry.

\begin{itemize}
\item[i -] \textbf{Political/Legal}
\end{itemize}

This section includes information on how the political environment, policies, and other legal aspects can influence a marketplace. Topics like environmental regulations, technical standards and building codes as well as governmental subsidies can be considered here.

\begin{itemize}
\item[ii -] \textbf{Economic}
\end{itemize}

Within a market, the flow of money is crucial. In order to get an idea of what role financial resources play, there are a few parameters that can be looked at. Some of them are the GDP, interest rates, housing starts, but also minimum wages and common square meter prices for certain building types.
iii - Social

The social aspect basically describes the characteristics of the customers and consumers within a certain marketplace. This can include age distribution, personal income and environmental awareness, as well as, the awareness for a certain product or service, and common social values or behaviors.

iv - Technological

Technology is constantly evolving, yet this does not happen everywhere equally and at the same time. The adoption of new technologies mostly brings great improvements, but can also involve significant investment and planning. Therefore, topics like evolving construction methods and IT adoption are of high importance, as well as the availability and accessibility of new innovations, expertise needed for operation, and R&D.

v - Demand

Demand basically depicts the willingness and ability of individuals in a market to buy a certain product. Further, there is elastic and inelastic demand, which basically describes how influenced it is to price changes. If there are many substitute products on a market, if consumers can decide to postpone a purchase, and if a product is relatively important, price dependence is high (elastic). This means little changes in price can have a great effect on demand. Au contraire, if there are no similar products, and if consumers are dependent, the demand is not as strongly correlated to the price (inelastic). (Bennett, Lamm, & Fry, 1988). Hansen and Juslin (2011) further explain, that certain factors can have a great influence on demand. Some of them are, GDP, economic growth, population, number of households, advertising trends, user trends, and environmental issues.
vi - Supply

If a marketplace is thought of as a big basket of apples, whereas each fruit resembles one physical product or service, the supply would be the action of someone putting apples into the basket. The demand as explained earlier describes the action of taking an apple out of the basket. This image helps to show that supply and demand are directly related. The price however is the third important variable in the market basket. If the demand in a marketplace is higher than its own supply, sometimes a foreign hand can start to feed apples into the system, which is called import. If the demand however is lower than the supply, or if the demand in another market wants to be satisfied, local hands can start reaching for foreign baskets. This is then called export. A higher level of quality, specialty or expertise can also create opportunities for importing and exporting.

vii - Competition

Within a marketplace, there most often is more than one company producing the same, or similar products. So, every company must define itself against others. In order to do so, there are certain characteristics, that are useful to know, such as a competitor’s recognition, investments, competing products and their strengths and weaknesses. Also important is their marketing and production and the raw-materials they use.

viii - Distribution

Hansen and Juslin (2011) explain that every market or country has a unique distribution system/structure. Often, there is a separation between retail and wholesale, and the explicit channels can vary widely. Distribution systems need a lot of structuring and must as well be operated. It is very important for a company to work with the right channels and
intermediaries. Transportation on the other hand is the physical pathway a product is
traveling from the producer to the user and usually is a part of distribution.

 ix  -  Customers

Professionals distinguish broadly between business-to-business (B2B) and business-to-
consumer (B2C) marketing. Depending on level of prefabrication and distribution channels
used, a certain customer group or type is chosen and targeted. In the building industry,
often times the end-user is not necessarily the producer’s direct customer. Architects and
general contractors are intermediaries in the building process, especially for larger projects.
However, some producers of building products and systems also offer additional services,
which could eliminate the necessity of intermediaries.

 x  -  Existing Structures in Market

As described in the introduction, existing structures build the crown for a CLT market. Only
if there are projects built in CLT that people can look at and experience, social awareness
and perception can grow. Also in terms of political and legal aspects pilot projects help with
the development of standards, codes and legal trust in the material. Also, projects that are
in progress of construction can be included in this section.

 b  -  BUSINESS MODEL VARIABLES

In order to get a comprehensive overview of the business models of individual companies
in the CLT industry, this thesis relies on a theoretical framework of categories. Most of them
follow the so called Nine Building Blocks of Osterwalder& Pigneur (2010). The last category
Strategies was added, so that a better understanding can be gained. All of these terms are further explained on the following pages. Following figure shows the categories used:

**Figure 5: Theoretical Framework – Business Models**

Since the term “business model” is used, it received a lot of attention and controversy. Many different professionals made up their own definitions and created their own unique understandings of the matter. Zott et al. (2010) analyzed different definitions for the term *business model* that were published in literature. Most of them are very complicated and long such as: “The business model depicts the content, structure, and governance of transactions designed so as to create value through the exploitation of business
opportunities.”, or “A business model articulates the logic, the data and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value.”. Michael Lewis (2000) on the contrary put it in to simple words: “All it really meant was how you planned to make money!”.

Taking this thought further, a business model is basically a plan which is made by a company itself or a consulting firms, which addresses the objective to create revenue. This plan is a collection of ideas and approaches on how things are done within a business. As a result, many different aspects and components have to be considered and mapped out. A common way of dealing with these components of a business model is the business model canvas by Osterwalder & Pigneur (2010), which is used as a framework for this research.

i - Nine Building Blocks of Osterwalder & Pigneur

Osterwalder & Pigneur (2010) describe the importance of a shared understanding when talking about business models. Therefore, they developed the business model canvas as a “shared language” with a structured set of categories which are called: The 9 Building Blocks. All companies and their business models can be defined through these main components, which makes it easy to accurately capture an image of a business including its ideas, values and other immaterial assets. The canvas itself is basically a graphic map or template, which divides all business operations and characteristics of a company into these categories. The individual boxes are then filled with company specific information which provides a good visual basis to work on and understand a business model. Because of its universal and complete nature, this system can be used effectively as a basis to describe and analyze the companies within the CLT industry.
ii - Customer Segments

According to Osterwalder & Pigneur (2010), "The Customer Segments Building Block defines the different groups of people or organizations an enterprise aims to reach and serve." They further call customers the “heart of any business plan", because those are the very people who either make or not make the decision to give a company money for a product or service. A business can also address more than one customer segment, by offering different products, forms of distribution, relationships, profitability, prices and values. In regard to CLT companies, it is interesting to see, if there are customer segments defined or not in the first place. If so, it is important to know, which segments there are. Does a company intend to produce for a mass market or a niche market, do they focus on more than one customer segment, or even have a diverse portfolio with several totally unrelated types of customers?

iii - Value Proposition

Osterwalder & Pigneur (2010) say, that this Building Block is about the products and services that a company offers to a specific target group. Each proposition is a collection of all value that is directed at one single group of customers. This value can be of innovative nature, meaning that the offer is new and unique, or it can also be more standard and comparable to other companies. For CLT companies this can describe first of all value that comes from the CLT material itself. Any type of special characteristics, like higher performance, different wood species, unique connectors, level of prefabrication and so on are part of this. In addition to that, aspects like postproduction manufacturing (customization), project planning, architectural design and any additional type of value added services are included in the Value Proposition block as well.
iv - Channels

The channels category as stated by Osterwalder & Pigneur (2010) is about almost everything that happens between a company and a customer and can be roughly divided into 3 main stages. Firstly, it includes the way any type of information, like advertising, news, practical information and ordering and sales data, is communicated between the two parties. Secondly, it describes the methods how a product or service is distributed to the customer. And thirdly, it involves customer support after a purchase. Due to its large dimensions and unique nature as a building product, sale and distribution of CLT are very important factors of its success. Since it still is a new product, it cannot be expected to be known by every potential customer. Therefore, the way a company advertises and markets itself is very interesting, as well as the facts how the communication between architects, planners, engineers and production works, what modes of transportation are used and who is responsible for the assembly on site. Also, aspects like building maintenance and supra-regional and supra-company advertising of CLT can be included here.

v - Customer Relationships

This Building Block is described by Osterwalder & Pigneur (2010) as a definition of what relationships a company wants to establish with its customers. They argue, that it is very important to have this clarified in advance. Depending on the decision made, different strategies must be pursued to attain the pursued goals. These strategies then drastically influence the customer experience of a specific target group. With regard to CLT, this section is shaped by the fact, that cross laminated timber is a high-end building product. Customers almost always need assistance before and after purchase. Therefore, personal assistance and co-creation of floor plans and building designs with the customer can be a big part of the whole experience. Furthermore, the Customer Relationship Building Block for CLT is
closely related to the Key Partnerships block, because a building is most often built by more than one contractor, which also drastically shape the customer experience. Many times, a CLT manufacturer’s customer is not even the end-user, but instead a carpenter or general contractor, which navigates the whole building process.

vi - Revenue Streams

In their book, Osterwalder & Pigneur (2010), talk about Revenue Streams like the arteries of a business plan, while the customers are the heart. Every Customer Segment can generate one or more of those money flows, depending on the amount of Value Propositions that are offered within them. Generally, there is two subcategories of Revenue Streams, which are directed towards the company. Firstly, there is the one-time type which is created upon the sale of a Value Proposition that comes from one single product or service. The other type is reoccurring. This means there is some kind of longer term value provided, which is usually a service. In the CLT industry, most contracts are related to the product itself and not repeated. Some companies however can also provide additional service value, like planning and project management, which can potentially create a different kind of money stream. Other types like subscriptions and leasing are not common in the CLT context, whereas licensing can have its place in rare cases.

vii - Key Resources

As Osterwalder & Pigneur (2010) say, the Key Resources are the most important assets a company employs to make a business model work. This Building Block, together with the Key Activities, is the base and origin of the all Value Propositions. As the word resources implies, all things are included that initially are needed to create a value. This refers to physical, financial or human resources, as well as intellectual. In case of CLT, Key Resources
are elements like raw materials (wood boards, adhesive, etc.), production facilities, trucks for transport, any type of initial investments, trained people who can run the production lines and do quality control, finally all the knowledge of how to make CLT. Further product certifications are often needed to sell to particular markets. In addition to that, certain intellectual resources like adhesive formulas or static calculations are needed, which can result in a need for certain individuals that have certain abilities, talents or knowledge.

### viii - Key Activities

Osterwalder & Pigneur (2010) states, that the Key Activities are “the most important things a company must do to make its business model work”. As mentioned, they are the second aspect needed to create a Value Proposition. These tasks can be related to the production of a product, or the finding of solutions for problems. On the other hand, the maintenance of some kind of platform or network, can be addressed here. Thinking of CLT, these activities are particularly production oriented. The raw materials must be made into CLT and the raw panels must be customized and distributed. Since it is a structural product, the production quality must be controlled on a frequent basis. If innovation has its place in a CLT business plan, also product research and development can be key activities.

### ix - Key Partnerships

Osterwalder & Pigneur (2010) state, that “The Key Partnerships Building Block describes the network of suppliers and partners that make a business model work.” There is a variety of different types of partnerships. Companies create alliances with partners to join forces and optimize their practices. Buyers and suppliers can agree on extended cooperation and in some cases even competitors form strategic partnerships. As briefly touched in the Customer Relations section, a CLT building project needs a great variety of different
contractors, because there is a wide range of technology and expertise involved. All these trades are often directed by a general contractor that makes sure everything and everyone works together correctly and efficiently. How CLT manufacturers fit into the bigger puzzle can be well described in this section, by analyzing their relationships with their partners.

x - Cost Structure

This Building Block, according to Osterwalder & Pigneur (2010), is all about the cost, that occur throughout the operation of a business model. Key Resources, Key Activities as well as Key Partnerships are the main sources of these system inherent costs and can be easily calculated once the previous factors are defined. In case of CLT, there are a lot of costs associated with the raw materials and the production of the panels. In addition, there might be costs arising from partner companies which help with the assembly on site or the transportation. Since these expenses are very much dependent on the individual business model, every CLT company is expected to have a unique cost structure.

xi - Strategies

In addition to the Nine Building Blocks of Osterwalder & Pigneur, the additional category Strategies is used. Thought processes and considerations of decision makers in companies that manufacture CLT are being captured. This additional focus makes it easier to find connections between market variables and business model variables, as business models often follow strategies that are influenced by and made around certain market variables.
According to Ojala (2017), the SWOT analysis technique was developed in the 1970s and has since then gained a lot of popularity. This simple method helps to describe and understand the relation of a company, product or industry with its market and is based on the four categories strengths, weaknesses, opportunities and threats. The first two are internal components, whereas the second two are external. If a SWOT analysis is for example done for a company, the internal factors could be a USP (unique selling proposition) and special expertise as strengths, but also inefficiencies or missing capabilities as weaknesses. The external factors describe the market that the company is acting in on the basis of certain opportunities that the company could take advantage of, or threats that should be avoided. By setting the internal values in relation to the external market environment, this tool can help to make strategic decisions and create a deeper understanding about the matter.
IV - METHODS

a - CONDUCTING CASE STUDIES

Yin (2014), describes case studies as one of the most used study techniques, alongside experiments, surveys, archival analyses and history studies. Each type takes a different approach to how research is being conducted. In the very beginning of a project, the researcher must consciously define which method is most suitable for the specific purpose, or what approach will lead to the most valuable and useable results. Yin (1994) defines Case Studies against other types of research through 3 main aspects. First of all, the addressed research questions mainly start with “how” and “why”, which supports that case studies are trying to look behind the facade to understand reasons, underlying concepts and origins of a matter. Secondly, the extent of control the researcher has is relevant. While conducting case studies, there are little to no means of actively manipulating the object or situation of interest. However, that does not mean that this method is entirely passive in nature. In fact, case studies, compared to e.g. a history study can be very active, since they can use real-life tools like observation and systematic interviewing. This leads to the third aspect that defines the nature of this research practice. Case studies usually deal with a set of contemporary events rather than the past. This is the biggest difference compared to a history study.

As mentioned in section VI a., the CLT industry is only slightly older than 20 years. This is a unique moment in time, where a case study approach, with the help of contemporary witnesses, can analyze current states of affairs and events, while at the same time, taking the historic development of the CLT market and industry into account.
i - Types of Case Studies

Depending on the amount of knowledge a researcher has about a research topic in advance, and the kind of results that she is expecting, different approaches can be taken. Broadly, Case Studies can be divided into the following three categories:

EXPLORATORY CASE STUDIES – Just like in any type of research, the exploratory phase is the beginning phase. Yin (2012) explains that exploratory case studies can follow intuition rather than a planned structure, which external observers often perceived as untidy and chaotic. Nevertheless, this freedom of direction and focus is actually the biggest advantage of an exploratory approach. A new topic can be mapped and an overview can be generated so that in further research a coherent structure can be introduced. The expected outcome of this type of research is a good foundation for ensuing research on the same topic. Yin (2012) calls it discovering theory. Even though exploratory case studies try to be very open and absorbing, they have to have some kind of a framework, a broader theme that helps keep the researcher’s attention and energy on the broad purpose of the study. A successful exploratory project gives an overall understanding and develops research questions, hypotheses, and design considerations that can be tested in subsequent research. It is very important though to use the generated exploratory data only for exploratory purposes. Even, if for example a descriptive research is based on hypotheses or findings of the exploratory stage, an entire new data set has to be collected and none of the exploratory data can be used.

DESCRIPTIVE CASE STUDIES – As the name implies, a descriptive case study has the purpose to describe a phenomenon. Yin (2014) explains that it is important to keep the focus on a specific topic and goal. Therefore, a higher degree of structure and theory must be developed in advance, to make sure every important aspect is addressed. At the same time,
a study can still be open to additional information outside of the predetermined scope. In comparison to an exploratory approach however, there is more structure, like predefined hypotheses at the beginning of the research and also the data collection can follow a particular framework. The aim of a descriptive study, however, is only to illustrate and understand a certain topic. Analyzing dependences or causes is not the goal.

EXPLANATORY CASE STUDIES – Just like for descriptive research, the word explanatory already gives away a lot about the strategy itself. It is about finding relationships and explaining how certain variables depend on others. Yin (2012) is dividing this approach into two subcategories according to the analytical methods used. The first one is called factor theory. Hereby a dependent variable and an additional list of independent variables is defined. Then data is collected, with the aim to find out which of the later ones could possibly cause the prior one. This technique is often used in quantitative research and therefore can have its issues when applied in case studies. The other strategy is called the “How” and “Why” theories. They are better suited for explanatory research. As structure and foundation, existing explanatory theories are used, which can often be fairly complex. This allows an extensive and structured collection of qualitative and quantitative data. To analyze the data, pattern matching techniques can be used, which can make it possible to explain complex topics in a single study. Without those the use of explanatory theories, this cannot be done.

ii - Validity of Case Studies

As described in the previous point, Case Studies are structured in a logical way. Yin (2014) further suggests, that there is a set of four logical tests which can be used to assess the quality and validity of a research design. They are called construct validity, internal validity, external validity and reliability.
CONSTRUCT VALIDITY – According to Yin (2014), construct validity is assessing the quality of operational data measurement. It basically evaluates to what degree a research construct can make sure, that the obtained data can be trusted. In case study research, this is the most discussed aspect of validity, because certain subjective data collection methods can rely on the researcher’s perception rather than clearly calculable facts. There are three tactics that can be used to strengthen construct validity. The first one, is to use multiple sources of evidence, so that common themes can be found. Secondly, a chain of evidence can be built, which basically means, that a study must be structured and cited in a way that all the pieces of evidence, like research questions, protocol, database, and report are tied together coherently and flawlessly. Lastly, the draft of a case study report can be reviewed by informants, which can help to prevent wrong interpretations and judgement. Construct validity can mainly be influenced in the data collection phase.

INTERNAL VALIDITY – Yin (2014) suggests, that internal validity is most often discussed with regards to experimental research. However, it can also have an impact on explanatory case studies, which try to find relations between events and factors. Also, it can be of concern if inferences are made, which can happen in case studies when an event cannot be observed directly. There is especially four specific tactics that can be used to increase internal validity. Pattern matching compares an empirical pattern that is based on a study’s findings with a second pattern that was predicted before data collection. Also, explanation building can create an explaining declaration about a case, which helps with the data analysis. Further, rival explanations can be addressed and tested throughout the process. As a last option, logical models can be used, which use a complex chain of occurrences and staged variables. All of them happen mostly in the analysis phase of a research.
EXTERNAL VALIDITY – As Yin (2014) explains that testing the external validity of a research project gives information on whether results can be generalized beyond the study boundaries or not. The wording and nature of the initial research questions is of importance. As mentioned earlier, case studies tend to favor “How” and “Why” questions. These types of questions can allow a research project to increase its generalizability, since they ask for underlying reasons and generate more information. This in turn is increasing the external validity of the findings. This can mostly be best influenced in the research design phase.

RELIABILITY – The last test for a case study is reliability (Yin, 2014). It basically is the idea to construct and conduct a case study in a way, so that if another researcher were to follow the same procedure on the same case, the results and conclusions would be the same. The higher reliability, the less error or bias is inherent in research. Yin (2014) mentions two tools that can be used in this regard. The first one is called a case study protocol, which is a short document that guides and ensures especially the data collection phase. The second one is a case study database, which is a systematic archive of all the data that is important to the study. These aspects have to be considered in the data collection phase.

iii - Generalizability of Case Studies

Even though case studies are often perceived as vague, Yin (2014) says it is common to generalize findings from a case study. Theory and theoretical propositions especially play a key role in doing so. Yin (2014) calls this technique analytic generalization and thus distinguishes it from generalizations that are drawn from empirical studies, which he calls statistical generalization. Statistical generalization is more common and relies on a population or universe for a research projects and all inferences are made on the population.
However empirical data is collected from a small sample of the universe only. This approach cannot be used for case study research.

Instead, analytic generalizations can be derived. Theory and theoretical propositions from the initial research design stage are further complemented by the empirical findings from the research. Together they build the foundation of analytic generalizations, while also new theories and concepts can emerge. Yin (2014) explicitly calls out two possible scenarios analytic generalizations can be based on. Firstly, theoretical models and frameworks referenced in a research project, which can be either confirmed, adapted, opposed or changed. Secondly, entirely new concepts that emerged in the case study can build a base. Yin (2014) further argues that this kind of generalizations is at a conceptually higher level, which means that they are closer to overall general theories on a certain topic. He also shows several examples of historic single-case studies which were able to generalize their findings far beyond their boundaries to a broad variety of situations.

iv - Single-p vs. multiple-case studies

Yin (2014) describes that there are advantages and disadvantages to both single- and multiple-case study approaches. If only one case is the object of research, a project can be done much faster and more inexpensive. However, generalizability and external validity can be considerably weaker. On the other hand, when the objective is looking at a very unique or extreme case, including more subjects or conditions can also be disadvantageous to the findings and conclusion. Nevertheless, Yin (2014) clearly suggests, if a researcher has resources for more than one case, a multiple-case approach should always be preferred.

Further, it is important to choose the right cases for a multiple-case study. Hereby the selection of the individual cases should not be done like the selection of respondents of a
survey, which means the selection is not based on sampling, but on replication (Yin, 2014).

In regard to this research, replication refers to the selection of the original and new markets. Each marketplace can be considered a case. The specific companies and individual that are chosen through sampling methods are the informants. Consequently, this research is a multiple-case study with 2 cases.

v - Data collection for Case Studies

Since case studies can deal with very diverse information, Yin (2014) explains that it is highly recommended to use multiple sources of evidence. He further describes the following six defined practices that can generate data for a research.

DOCUMENTATION – For many case study cases, a researcher might find some kind of related written documentation. This can include many different documents like letters, diaries and notes as well as meeting minutes, agendas, proposals and reports. Sometimes even formal studies, evaluations, articles or news can be available. Nowadays, many of these can be found online, which makes them more accessible and the process quicker. Especially before doing field research this can help to get an initial good understanding of a matter. All information gained through documents however should be carefully assessed and interpreted, since the purpose behind each of them is usually not the same as the purpose of the case study research. Documents are a stable and broad source of evidence, whereas they can sometimes be hard to find or access (Yin, 2014).

ARCHIVAL RECORDS – Another secondary source of data are archival records. They can either be public files provided by e.g. governments or be more specific like service and organizational records like numbers and budgets. Also, geographical information like maps and charts can be useful, as well as survey data that was produced by someone other than
the researcher. Archival records can be a very precise source of evidence, but can also be hard to access when being private (Yin, 2014).

INTERVIEWS – According to Yin (2014), interviews are one of the most important sources of information for case studies. However, they are different to e.g. survey interviews, while being more fluid and can be called “in-depth interview” or “unstructured interview”. The biggest challenge for the researcher thereby is the fact that she has to focus on leading the conversation to essential topics while at the same time being flexible enough to ask conversational questions naturally. A big advantage of case study interviews is that they create very insightful information that is specifically targeted at the research objectives. At the same time, it is crucial to be well prepared, so that potential biases can be eliminated.

DIRECT OBSERVATION – Since case studies usually deal with an actually existing case, direct observations are often a feasible and rich source of evidence. Depending on the nature of the case study, actions, habits, facts, uses and the like can be observed in real time. This can provide valuable additional information about a case in a real-time and real-life context, which is a great advantage. Conversely direct observations can be time-consuming and expensive which can lead to selective insights (Yin, 2014).

PARTICIPANT OBSERVATION – In contrast to direct observations, the researcher takes on a certain role within the case that is to be observed. That way participant observation can provide deep experience based insights. This source of evidence can be very challenging for the researcher. In addition to observational tasks like recording and note taking, the participant role can require a lot of attention and dedication. This and the fact that the evidence is based on the researcher’s experiences and interpretations can be create biases.
Nevertheless, this method provides great potential to gain access to underlying motives and interpersonal behavior (Yin, 2014).

PHYSICAL ARTIFACTS – A last source of evidence can be physical artefacts. Hereby any kind of object that is related to a case can be analyzed and examined. This can reveal insightful information on cultural or technical topics which could otherwise be hard to find. However, artefacts can be hard to find and may provide only selective evidence (Yin, 2014).

vi - Analysis of case studies

Yin (2014) describes the analysis stage as one of the biggest challenges in case study research. One of the reasons, is that every case is unique. Beyond that, there are not many commonly used analysis procedures existing, like in statistical analyses. A researcher’s empirical thinking is the most useful tool to create an adequate presentation of the evidence. Yin (2014) further states following four general strategies that can help a researcher to get started with a sound case study analysis:

RELYING ON THEORETICAL PREPOSITIONS – This strategy suggests using the theoretical propositions that led to the case study in the first place for its analysis also. These initial propositions originally helped to define objectives and research questions of the study, which in turn provided a base for the structure of data collection. Taking this simply one step further, the analysis can be structured along the same lines, so that initial propositions as well as hypotheses and research questions are addressed by the primary focus of data analysis (Yin, 2014).

WORKING YOUR DATA FROM THE “GROUND UP” – In contrast to the previous strategy, this one suggests to simple dive into the data without any preparation or preconception.
This clean start allows the experienced researcher to find new patterns or concepts. These in turn can be starting points for analytical paths that lead to further relationships. However, this approach works best if a researcher is knowledgeable about the field of research, since lack of knowledge also means lack of understanding the relationships in a topic (Yin, 2014).

DEVELOPING A CASE DESCRIPTION – This third strategy makes use of descriptive frameworks to organize case study data. If the initial purpose of the research was descriptive in nature as well, this approach can be used very easily. However, it can also be used for studies that were not descriptive in the first place. The only matter of concern is, that the introduction of descriptive categories needs data to support all of them. Therefore, it would be wise to consider these analysis frameworks prior to data collection. Doing so, the information gathering process can be adapted so that data are collected for all important topics. Ideally, the descriptive structures emerge from the initial review of literature, before the beginning of the case study itself (Yin, 2014).

EXAMINING PLAUSIBLE RIVAL EXPLANATIONS – The last analytical strategy can work hand in hand with the three previous ones. Hereby, rival explanations are being defined and tested. This approach also needs good preparation, because not only the original explanations need to be supported by the collected information, but also all the competing ones as well. Therefore, possible rival explanations need to be identified prior to data collection, so that information about them can be gathered as well. Simply speaking, the more an analysis can address, the more confident and comprehensive the final case study findings can be (Yin, 2014).

This research mainly focuses on the third analysis strategy. Even though the nature of the study is exploratory, a simple descriptive framework was created, prior to data collection.
This structure included specific categories for data collection as well as data analysis. The whole concept of the framework is explained in the next chapter.

**b - RESEARCH FRAMEWORK**

The following graphic shows the overall framework of this thesis. First of all, the whole data collection is divided into two main sides, the *market side* and the *business side*. On the following pages, this structure is further described:

![Figure 6: Theoretical Framework](image-url)
The *market side* (green) consists of a number of market variables which describe the market for CLT, meaning all factors external to manufacturing. The *business side* (blue) on the other hand, is composed of a set of variables that help to describe the business models of CLT manufacturers. These categories are specified to guide the process of data collection and are explained in detail in section V.b.i.

The following data analysis is then divided into two *result stages*. The first one is called *market characteristics* and addresses the first research question. Whereas the second stage is called *lessons learned* and is aimed at answering the second research question.

### i - Structure for Data Collection

As mentioned earlier, the process of data collection is oriented around theoretical frameworks, which are designed to provide guidance and make sure all the important topics are covered. Keeping in mind this research is exploratory, the introduced degree of structure is comparatively low, to keep it open to additional information that was not anticipated. The following graphic shows both sides of the data collection framework:

![Figure 7: Structure for Data Collection](image)
Both sides of the research rely on a set of variables that are predetermined before data collection. The *market side* is making use of a list of *market variables* which help to gain a very good impression of the character and nature of a marketplace. They are based on existing forest products marketing theory and are further described in section IV.a.

The framework for the *business side*, is structured around a set of *business model variables* called the *Nine Building Blocks*, by Osterwalder & Pigneur (2010). These categories can be used to describe nearly every business model and are further explained in section IV.b.

### ii - Structure of Results

All results and findings that are discovered throughout the entire data collection process of the case study, are, as mentioned before, divided into the two stages *market characteristics* and *lessons learned*. Following graphic shows those two stages:

![Figure 8: Structure of Results](image)

The first stage is structured around *SWOT analysis* (section IV.c.) and aims at creating a comprehensive understanding of the individual CLT markets through describing first of all the *opportunities* and *threats* within a market. These factors are used to describe what drivers and challenges CLT manufacturers might face in a particular market. They have their origins
external to the boundaries of a company and cannot be influenced directly. On the other hand, every manufacturer has to react to their surrounding market and its characteristics. This ability of reacting combined with other internal aspects can be described by the strengths and weaknesses of a CLT manufacturer. These factors are also part of the SWOT analysis. Together, those four categories provide a simple and comprehensive overview of a marketplace and the companies operating within.

The second stage comprises all the lessons that were learned over time. Due to the long history of CLT in the Original Market, there is a lot to be found in the German-speaking alpine region of Europe, but new markets can also be a rich source of lessons learned.

Altogether, this structure for data analysis and results helps to get a good impression of all the market influences that affect CLT manufacturers within their geographic area of operation. Understanding nature and traditions of a market is crucial for a successful implementation of the lessons learned, so that they can be introduced into the respective context of an individual market.

c - SAMPLING

This section explains the concepts that are used as foundation for data sampling in the data collection phase of this research. For the market side, experts are interviewed. Those are different individuals that command over a great amount of knowledge regarding CLT and its markets. For the business side decision makers, in companies that manufacture CLT, are talked to. These individuals are further simply referred to as manufacturers.
Within this research, the global CLT markets and the CLT producers within are divided into two categories. The original CLT market and new CLT markets. This separation is based on the historic development of the product CLT, which is further explained in section VI.a.

The first category describes the "original" market where CLT was developed and firstly implemented. Muszynski, et al. (2017) call it the alpine cluster in Europe. Within this research however, the term “German-Speaking Alpine Region” is used to define this area. The second category covers “new” markets that emerged subsequently to the Original Market over time.

As described in the previous paragraph, the oldest and initial market for CLT is in central Europe. This area includes Austria, Switzerland, Southern Germany and South Tyrol in Northern Italy. This is where the highest density of CLT manufacturers can still be found. Most of these companies are within the geographic region of the alps. Besides that, almost all of them are located in areas where German is spoken as official language. Therefore, the definition: German-Speaking Alpine Region is introduced, which defines the most mature or Original Market for CLT. In the initial phase of this research it was anticipated, that most lessons learned could be found in this geographic area. However, the data collection shows, that also new markets have learned lessons that are worth sharing. The following map gives an idea of the original market:
As an example of a new market, North America (NA) is focused on within this study. Within this research, the term North America only refers to Canada and the US, since those are the only countries in NA where CLT is starting to play a role on the market. The same tools of data collection and analysis are used for all markets. That way a comprehensive comparison can be made, which is the foundation for an effective implementation of the lessons learned.

ii - Selection of experts and manufacturers

Within the original CLT market, there are many different manufacturers and experts. Throughout the years, new companies came on the market, existing businesses have changed and associated individual became experts for CLT. In order to find the best
informants for obtaining data that is rich in experience, history and diversity, this research makes use of a variety of different sampling techniques.

In terms of experts, a combination of 3 sampling techniques is used. The overarching approach is sampling for maximum variety. This means purposefully trying to include a great variety of participants (Patton, 2002). Following that, the first few interviewees are chosen through convenience sampling, in order to get started fast and create a basis for the third sampling method being snowball sampling. Using this common sample approach, every interviewed person is asked for references of other individuals that could also be valuable sources of information (Patton, 2002). Following these methods, a great variety of different CLT experts, like university professors, trade journal editors, architects, engineers, and more, were identified and interviewed to once again ensure rich data.

Sampling for manufacturers required a slightly different set of techniques. Secondary research shows, that North America only has 7 operating CLT manufacturers. In that case all of them are contacted and invited to participate. In the Original Market however, there is a bigger number of manufacturers, of which some have been in operation for a comparably long time. Therefore, the overarching approach is criterion sampling. This means choosing informants by establishing criteria that have to be met before being considered (Patton, 2002). In this case, the only criteria for manufacturers in the Original Market is being in operation for at least 5 years. Following that, convenience and snowball sampling are use in the same way as for experts.

Further, there is no fixed sample size defined in advance. Interviewing with experts and manufacturers is stopped, whenever data saturation is reached. This is achieved, when the
data that is received from the last interview is not showing significantly new and useful findings compared to previous interviews.

The final number of interviews conducted was 19. This included six experts in North America and five experts in the Original Market, as well as three manufacturers in North America and five manufacturers in the Original Market. The following graphic shows the number of informants and their distribution.

<table>
<thead>
<tr>
<th>EXPERTS</th>
<th>MANUFACTURERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORTH AMERICA</td>
<td></td>
</tr>
<tr>
<td>ORIGINAL MARKET</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 10: Informant geographical location and type*
d - DATA COLLECTION THROUGH SECONDARY RESEARCH

As a very first step, secondary data are collected. The goal hereby is to get a first understanding of the topic and to get information to build, verify and advance the initially chosen theoretical constructs. A variety of different approaches and sources are used.

i - Web search

As a starting point, standard web search tools are used to find out what kind of secondary information is existing and available. The search engines Google and Google Scholar are used mainly, because of their accuracy and sheer volume of content. In order to increase the chance of finding helpful information, different search terms are used. Along the same lines, the search is conducted in English and German. The reason for this is that a great deal of research is done in the German-speaking alpine region of Europe, even though most internationally relevant research or information is generally accessible in English as well.

ii - Databases

In order to successfully navigate through the complex world of academic journals and publications to the few documents that are significant to this study, various databases are consulted. Some of them are library databases, for example of Oregon State University, Salzburg University of Applied Sciences, and Graz University of Technology. Other ones are more general like Gale Business Insights, Web of Science, Science Direct, etc.

iii - Non-academic publications

Through the described search tools, a variety of magazine articles, newspaper articles and different kinds of web posts on CLT and its markets can be found. One very important non-
academic source is the Austrian trade journal Holzkurier. Periodically, they publish on the
development of the CLT industry and also include information on new production lines and
professional estimates of future plans and developments within the industry.

Papers & studies
There is a great amount of studies done on the topic of CLT. However, most of them focus
on technological or structural aspects and very few are about market related issues.
Nevertheless, the studies that are existing are of high value for this research and are
considered an important part of secondary data.

Books
Since the industry and market of CLT are comparably very small, new and in the current
stage also very concentrated in certain regions, there is very few books available on CLT.
Also, none of them talk about market aspects. However, books are an important source of
information regarding research methods and theory.

DATA COLLECTION THROUGH PERSONAL INTERVIEWS
The main source of information for this research are personal interviews. They are conducted
with experts and decision makers in CLT producing companies. The following pages explain
techniques and methods used throughout the process of collecting interview data. A
detailed interview protocol can be found in the appendix.
i - Personal interviewing in context

Within qualitative research, there are two main procedures for how to deal with a topic, the direct approach and the indirect approach. First informs the participants of the purpose of the study and can therefore be called undisguised. There are again two techniques which are most commonly used for this type of research. Focus groups and personal interviews. Both will generate qualitative data and are primarily used for exploratory research. In contrast to focus groups, personal interviews are conducted in a conversation-style setup with only one interviewer and one interviewee at a time (Malhotra, 2016). This allows the skilled questioner to deeply learn about a person’s attitudes and emotions as well as to develop a profound understanding of a specific research topic. Usually such a session takes about 30 minutes up to more than an hour (Malhotra, 2016). All these aspects make interviews the perfect tool to explore and study the global CLT markets.

ii - Developing questions

Gillham (2007) describes, that the three main qualities of good interview questions are clarity, focus and economy. He says expert interviewers develop their questioning around these three qualities. This means that the question wording should be as clear as possible, so that the interviewee can spend all his conscious and unconscious thinking effort on answering and not on understanding a question. This will help to obtain answers and information that is clearly focused on the research question. By doing so, interviewing can be done more efficiently and economically.

iii - Structuring of interviews

An important part of conducting interviews is structuring them. According to Gillham (2007) this can be divided into 3 main types: unstructured, semi-structured, and structured. All in
all, it is about the "degree of structure". The higher this degree is, the more control an interviewer has over a conversation, but also the more restricted the interviewee is in her answering. For those reasons, mostly unstructured approaches are used for exploratory or preliminary approaches. Usually, the researcher asks one open question at the beginning and the rest of the time the informant is talking and navigating by himself through thoughts and memories, which often gives new and unexpected inputs into a matter. Only from time-to-time, a spontaneous probe can be brought-in by the listener, if she thinks a topic is worthwhile spending more time and talking on. Introducing more structure into a research project on the other hand, gives more uniform results across interviews in a study, while at the same time substantially narrowing the view and range of content.

The nature of this thesis is exploratory, which leads to the decision that a lower degree of structure is more adequate. This way, a greater variety of information can be collected, which gives a better overview of the CLT industry and its history. To make certain that key aspects are addressed in the interviews, a slight amount of structure, is introduced, so the method can be considered semi-structured.

A short list of four open interview question is defined which help to start the interview into the right direction. The first two of them are based on the structure of results, being the SWOT analysis. So, experts are asked for opportunities and threats within the CLT market and manufacturers for their strengths and weaknesses. The third and fourth questions are about how the future of CLT is expected to develop in North America and what lessons can be learned from the Original Market in Europe. This approach ensures, that a great variety of data can be generated. To make sure that the overall goal of the research is always being addresses, further probing was used.
iv - Probing

Gillham (2007) suggests, that a skilled interviewer must guide the informant in his answering with as little effort and disturbance as possible. Often there are no additional questions needed, but merely a single word or phrase at the right time. Especially unstructured interviews need this type of guidance, so that an informant is sensitively encouraged to give information that is relevant for the research rather than to stray from what is important.

For this research, a specific probing framework was developed, which is based on the market variables and business model variables of the data collection framework. A detailed explanation can be found is section V.b.i.. These categories are then used at hand during the interview to guide the researcher in his probing, to make sure all the important topics are addressed by the informant. Since probing is a creative and dynamic process, there is no clear how-to-do guide, but there are a few different types of probes which function in certain ways. Here are a few of those techniques:

CLARIFICATION – Even though people might have a clear idea in their heads, it is not always clear that the vis-à-vis understands something the same way. If an informant is asked for clarification, he has to rethink a statement and spend more time and explanation on it. This will generally reveal more detail and further insight for the researcher. Asking for clarification is best done other than in form of a question (Gillham, 2007). For example: ‘I am afraid I did not fully understand’

APPRECIATION & UNDERSTANDING – Showing emotional involvement is a very personal and sensitive way of reacting to an answer. If done subtly it can emphasize a good connection and rapport, but if exaggerated and done overly ambiguously it can also create distrust and distance. For example: ‘That must have been difficult’ (Gillham, 2007)
EXAMPLE – When an informant is asked for an example, he must rethink and sort thoughts on a topic and scan through memories and ideas. This can focus and bring some underlying topics on the table. Simple and easy (Gillham, 2007).

REFLECTING – This technique is a very advanced form of probing. Only when managing an interview is second nature to the interviewer should it be attempted. Essentially it is a simple concept. The researcher reflects back what was said by the interviewee in slightly different words. This way certain facts and details can be emphasized on and if done with care and finesse, deep underlying thoughts and emotions can be addressed (Gillham, 2007).

- Ethics of interviewing

Interviewing someone can reveal very private information about a person or individual. In fact, this is often what researchers are aiming for. Therefore, the whole process should be done in a very ethical manner. First of all, it is ethically sound as a researcher to provide all participants a clear understanding on who you are and what the purpose and nature of your research is. This gives both, the interviewer and the interviewee ease of mind and a defined foundation to build a successful interview on. It is very important to always treat all acquired information and data with utmost care and discretion. Confidentiality is crucial. This starts with asking for consent before data collection and goes as far as securely storing the data. A key part of doing this, is to protect the identity of the participants. The final results should never be connected to any personal information of a participant, so that their anonymity is being sustained (Gillham, 2007).
According to Gillham (2007), transcribing and analyzing the recorded interviews are the most time-consuming step of the qualitative research process. Realistically, each hour of recorded interview will take about 6 to 10 hours to transcribe. Clausen (2012) sees this as a significant disadvantage introduced into qualitative research if traditional transcription methodology is followed, as it limits the researcher to a smaller number of interviews that can be done in a feasible amount of time. If a long time passes between data collection and analysis, also the quality of analysis of written transcripts suffers, since the researcher’s memory of the interview itself will fade over time and a plain text analysis is done in the end. Another significant threat of having a large number of pages of transcriptions, is that the researcher might have troubles to see the forest for the trees and consequently miss or overlook important findings.

Therefore Clausen (2012) suggests that, under certain conditions, qualitative interviewing can be done without the need of a full audio transcription. The resulting research method that addresses these issues is called: The Individually Focused Interview (TIFI). The TIFI methodology by Clausen (2012) omits the need for the widely-used audio transcription process by relying on verified field notes only. According to Clausen (2012), this allows a larger number of interviews to be conducted. After the interview, the field notes are shared with the respective interviewees to ask for comments or changes on the collected information. Afterwards, all verified field notes are combined to a data set, which is used for subsequent data analysis.

Further, Clausen (2012) states the following condition under which TIFI can increase reliability, validity and transparency. The first one is a heterogeneous group of informants. The more variety, the broader the range of collected statements can be. That assures
comprehensive findings. The second condition is that the interviewees must be educated about their role in the research and what responsibilities it brings. Thirdly, the purpose of the research makes a difference. Especially if consistent topics of information need to be collected across all informants in order to describe nuances associated with the research question, this approach has a positive impact. The last condition is the methodological aspect, in particular when the researcher wants to find immediate discourses on the research topic, predict trends and describe social dynamics.

In the data collection phase of this research project, interviews are conducted with two main groups of informants. Manufacturers and experts. Those experts further are a very diverse group of people, as explained earlier. All of these individuals have extensive knowledge about CLT and the different CLT markets, however their points of views on these topics are highly different, which makes them a varied and rich source of information. This matches the first condition of Clausen. The second condition is addressed in the introduction of all individual interviews, where informants are educated about the scope and objectives of the research and their own role within. In response to the third condition, this research makes use of theoretical frameworks, which are used throughout the whole progression of the research, also personal interviewing. The last condition is fulfilled by the nature of this research. The dynamics of different CLT markets are focus on and current and future trends are identified as part of the objectives.

Therefore, The Individual Focused Interview methodology is chosen over other qualitative research techniques. However, data reliability in this research is ensured a little differently than in Clausen’s (2012) TIFI. Instead of only relying on field notes and the interviewee revision process, every interview, with the permission of the informant, is audio recorded. After the interview, the researcher listens to those recordings again and creates an additional
set of notes. Those audio notes are then compared and merged with the field notes. The result is a comprehensive set of information blocks from each interview. These are pieces of information that are found or given throughout the study. If for example an informant mentions the same thing as a previous one, both statements are combined into one information block. They are then used as foundation for data analysis. In case an informant does not give consent for audio recording, Clausen’s (2012) original approach is used and a digitalized set of field notes is sent to the interviewee after the interview for revision. The following graphic illustrates the adapted TIFI approach used in this study.

In order to verify the reliability of the approach to use audio notes from audio recordings instead of the original interviewee revision process, two test rounds are done. Thereby the researcher and another independent academic person are listening to the same audio recording independently, taking notes. Afterwards the content of these audio notes is compared. When the information content is the same or very similar this adapted approach of the TIFI methodology is considered reliable and transparent. Both test runs were completed successfully.
f - OBSERVATIONS

Observations are almost exclusively done for the business side of the research, since there is more to observe in a company. Therefore, whenever an interview with a CLT manufacturer is done, also their plant is visited upon their permission. During the mill tour, the researcher tries to get a comprehensive understanding of a production line and the processes behind it. If possible, questions are asked throughout the visit also, to clarify points and get access to underlying thoughts and strategies. All the information gained is later combined with secondary and interview data to create a comprehensive final database.

g - DATA ANALYSIS TECHNIQUES

The data analysis stage of this research is taking a simple structured approach. As previously discussed, a few minimal frameworks and factors are used to structure the collected data and extract the most valuable and reliable results. This approach makes sure, that all the findings are of high quality.

At first, all information gained through data collection is combined to a complete database. This includes material that is gathered through secondary research, personal interviewing and observation. The individual information blocks provide a mechanism that the data are both comprehensive and non-redundant.

Furthermore, the market characteristics stage and the lessons learned stage make use of slightly different analysis approaches. The first one divides the respective information blocks into the subcategories of the SWOT analysis. Following that, findings of the Original Market and the new North American market are compared to each other, within these four
categories. This structure helps to create a good awareness of the differences between the two markets and the manufacturers within them, which in turn builds the basis for the second stage.

The lessons learned stage on the other hand, uses two significance factors that help to measure how relevant a piece of information is. They are introduced for every single information block within this stage. The "Number of occurrence" describe how often this element occurs throughout all data collection. Only information blocks that are mentioned by more than one independent source are further discussed, all others are considered non-trustworthy. "Perceived importance" on the other hand is a value on a scale from 0 to 3 that is assigned to every source of an information block. If there is more than one source, a median is calculated and then associated with the entire information block. This final factor is only used for interview data and describes, how important a piece of information seems to be for the informant that provided it. If an information block is only mentioned one time, but its perceived importance is very high (close to 3), additional secondary research is conducted, to make sure no important findings are lost. Figure 12 shows the process of using the significance factors.

![Figure 12: Significance factors](image-url)
Together those factors and frameworks help to structure the collected information. This makes it possible to extract topics of high importance and significance from information that is not valuable or reliable.

**h - RELIABILITY & VALIDITY**

Within this research some preventative actions were taken, to make sure that the collected data are both reliable and valid. By doing so, the research methods are carefully structured and thereby verified, so that the findings and results of the study can be a trustworthy and valuable contribution to the greater research field.

Yin (2014) describes that *reliability* means being consistent and repeatable. With that in mind, a few tools are put in place to achieve a high degree of reliability. The first of those tools, is a uniform interview protocol. This document is used to guide every single interview and helps to keep a consistent procedure throughout the whole data collection phase. It also provides, along with the methods section of this thesis, a transparent guide for following researchers to the methods that are used in this study. The second instrument that helps to increase consistency and reproducibility, is the framework used for data collection. Further explained in section *V.b.i.*, this structure is based on existing models and is used during the data collection process to guide the gathering of information. That way, it can be made sure, that also every conducted interview consistently covers the same key topics. This framework is also included in the interview protocol.

Further, the *validity* of this research is focused on. Especially the *construct validity* has a significant impact on how trustworthy and applicable the final findings are. A technique used to achieve a high construct validity for this research, is diversification. What this means is,
that purposely a diverse variety of informants is chosen. This is first of all realized by dividing the whole data collection into two main sides. The *business side* uses CLT manufacturers as informants, whereas the *market side* is focused on CLT experts. These experts furthermore are a group of very diverse individuals as explained in section V.c.ii. In the data analysis phase, all the information gained by all informants is then combined and patterns of evidence and repetition are extracted. This methodology makes sure, that the results obtained by this study are highly valid.

The *external validity* of this study on the contrary, is influenced by the underlying research design. An exploratory case study approach is chosen and research questions are designed accordingly, so that underlying reasons and causes are targeted. This way, a broad range of information can be obtained, which in turn builds a solid foundation for generalizable findings. The generalizability of this research however is different to statistical generalization found in quantitative research. Yin (2014) calls is *analytic generalization*. Within this research *analytic generalizations* are firstly based on theoretical models that were pre-defined in the design phase of the study, and secondly on new concepts that emerged from data analysis.

### i - MINIMIZING LANGUAGE BIAS

Along with the focus on reliability and validity, a few control mechanisms were put in place to minimize possible biases that could emerge. This is a very important step to make sure a research keeps a high standard.

Within this study, the biggest bias potential lies in the fact that the study is conducted using two different languages, being English and German. Within the whole research process, translations are done two times. Firstly, the original interview questions and the *probing*
framework are prepared for German-speaking informants in the original CLT market. Secondly, the information collected through these German interviews is translated back to English language before data analysis.

To mitigate risk of error in those areas, the help of independent researchers is asked. During interview preparation, all questions are translated from English into German by the primary researcher, then an independent researcher, that is bilingual and understanding of the matter also, is asked to translate the German version back to English. This English version is then compared to the original English questions to make sure that content and meaning are still the same. Afterwards minor edits are done to both the original English and the German versions to make them as clear as possible. This was done successfully.

A similar measure is used to verify the translation process of the German answers. The audio recording of one of the interviews conducted in German is being processed by the primary researcher and an independent researcher simultaneously and independently. Then both answer translations are compared, based on their information content and completeness. If the result shows that both translations are very similar and equally comprehensive, the translation process is considered verified and reliable and is being continued for all other interviews by the primary researcher only. This test was completed successfully.
V - RESULTS

a - THE HISTORY OF CLT

CLT, as it is known today, cannot simply be traced back to one individual inventor. It rather was an evolutionary development, by several pioneers. At the end of the last century, the wood products industry already had a wide portfolio of structural products. For example, LVL was available for linear applications and plywood was used two-dimensionally as a panel. Both were made from veneers. On the other hand, glue laminated timber (glulam), first patented in 1906 in Germany (Müller, 2000), was made from boards. Glulam can be used for linear applications such as beams and other structural members that span one-directional. However, there was no structural panel product made from boards that could carry two-dimensional loads. The “cross” was missing. So CLT, or Cross Laminated Timber, was the logical next step in the evolution of structural timber products.

Dröge and Stoy (1981) were the first to publish the term “Brettsperrholz” (German for CLT), followed by Steurer (1989). Yet, CLT as it is known today really started to emerge in the early 1990s. Between 1989 and 1994, Gerhard Schickhofer worked on his dissertation on rigid and flexible laminated composite structures with focus on CLT, at Graz University of Technology, and in 1993, P. Schuler and R. Guyer developed and built the first ever building, a single-family home, using massive wood panels in Switzerland (Schickhofer, 1994). However, in 1995, K. Moser, built the first building out of CLT as it is known today, in Aichach, Germany (Brandner, et al, 2016). This precursor of modern CLT construction was a 3-story apartment building with CLT walls and concrete filigree floors and is still in operation. Simultaneously, in 1996 the company KLH was established by the three saw mill owners H. de Monte, W.
Weirer, and H. Lercher. Together with the Graz University of Technology these pioneers developed one of the first commercial production lines for CLT in Katsch, Austria, which today is one of the largest production facilities worldwide. Another pioneer who was involved with CLT production at this early stage was Helmut Stingl in Styria, Austria.

On a university level, the Graz University of Technology with Gerhard Schickhofer has done extensive and continuous research on the product and beyond, since 1994. More than 50 master’s projects were completed around CLT only, and many of them were done in cooperation with the wood products industry. Every one of those projects, in addition to the theoretical knowledge, also produced a well-educated master’s graduate, of whom many now work in the CLT industry.

The next notable step was the first license for CLT as structural material, an Austrian technical approval (German: ÖTZ), which was issued to KLH in 1998, followed by a general building inspectorate approval (German: Allgemeine bauaufsichtliche Zulassung) for Merk Timber in Germany later in the year 1998 (Bogensperger & Schickhofer, 2010). It was not until around 2005 -2010 however, that other large producers entered the market and started producing CLT. Names like Mayr-Melnhof, Binder, Hasslacher, Stora Enso, and more emerged in the CLT scene and the growth of the product in the Original Market (German-speaking alpine region of Europe) took off. Further, in 2009, the 9-story Murray Grove building in London was designed by Waugh Thistleton and constructed by and KLH, which was one of the first tall CLT buildings. This particular project caught considerable international interest and publicity, which opened many doors for CLT globally. There are now several new markets for CLT worldwide. Within Europe, Scandinavia, UK and France are important future markets (Schickhofer, et al., 2017). Outside of Europe, Japan, North America and Oceania show the
largest potential. Besides that, many other countries and regions are starting to show interest in CLT.

b - MARKET AND BUSINESS CHARACTERISTICS

A market is a steadily changing and evolving economical chessboard with strategically transforming chessmen and players. In the case of CLT, the board is growing and expanding. This part of the thesis results aims at comparing the Original Market (OM) in the German-speaking alpine region of Europe with the North American market (NA). This comparison is based on the SWOT analysis (figure 10) and includes opportunities and threats in the individual markets, as well as strengths and weaknesses of the manufacturers within. In addition to that, a general comparison is made, which helps to understand the different natures of the markets, before talking about specific positive or negative aspects. Following graphic shows, the categories of the SWOT analysis:

![Figure 13: Results stage 1: SWOT analysis](image)

i - General comparison

The Original Market and NA have noticeable differences. Some are a result of the historic development of CLT while other differences are due to their respective history, traditions, and economy. On the following pages, these are described in more detail.
EXISTING MARKETS – One clear difference is the number of existing CLT projects. Austria for instance has the second highest number of existing CLT structures per capita (after Iceland with about 4 projects and 330,000 people). Also, in the Original Market, the majority of projects were originally detached single-family houses, whereas by now also multi-residential, commercial, public and mid-rise buildings are being built. In North America, on the other hand, there is little demand for single-family housing in CLT. On the contrary, especially larger structures like multi-story residential and mixed use, as well as commercial and public type projects describe the majority of CLT used there. Besides that, the OM has a number of mid- or large-size manufacturers that are in operation, of which most are located in southern Austria. Their individual production lines are very diverse, ranging from high-frequency pressing and pneumatic cold-pressing to vacuum pressing. North America on the other hand, only has seven CLT manufacturers: Structurlam in BC (Canada), Smartlam in Montana (US), DR Johnsen in Oregon (US), Nordic in Québec (Canada), CLT Outaouais and Guardian Structures in Ontario (Canada) and Sterling Lumber in Illinois (US). Sterling has the largest production capacity, but produces CLT access mats only. As a result of that, professionals and owners in the OM are much more aware of CLT. In North America, awareness is comparably low, even within the construction industry. However, architects and developers and also hotel chains are starting to get an idea about the product.

MENTALITIES – Experts describe the differences in the single-family detached housing industry by analyzing the mentalities and values of the respective building cultures and offer the following explanation: In the OM in Europe, people tend to have a more fixed center of life. A traditional way of thinking, is to plan a house in a way that it can be passed on to the next generation. Therefore, quality and security are of high value to them. Both can be provided by massive construction systems like brick, concrete and stone, which therefore are the predominant building types in this market. CLT provides a massive solution in wood
that can offer the same values and is therefore used a lot for single-family homes. In North America however, people are more likely to geographically move their center of life within a lifetime. This fact significantly decreases the number of years spent in a house by the same residents, which in turn lessens the need for longevity and increases a request for flexibility and affordability. This is why light-frame construction is so successful for housing in NA and CLT is mostly used for larger structures. Mallo (2014) confirms this, by finding that CLT experts in North America do not consider the single-family residential building sector a potential market for CLT in North America, because the dominating wood-frame construction system is more efficient and cost-effective.

PLANNING PROCESS – The planning processes also vary greatly between markets. In the OM, most CLT projects are done in cooperation with carpenters. These are highly skilled wood workers that often have been in operation for several generations. Especially for single-family homes, these professionals are mostly the direct link between owner and manufacturer. Due to their high level of expertise, they can do installation, planning and some calculating under one roof. Some carpenters even have a CNC machine and thus also the capability to do the fabrication of raw panels. For larger projects, an additional architect, engineer and general contractor can be brought on board the design team. Often carpenters are then contracted by the general contractor to do the installation. The planning process in North America on the other hand, is much more rigid and linear, following certain procedures. The most common process is called Design-Bid-Build (DBB). Hereby, a developer or owner approaches an architect to design a particular project. At some point, an engineer is brought into the process as well. Then, the architect issues a call for bids to which general contractors can respond. Based on those bids, a general contractor is chosen. The price estimates are usually made using cost-per-square-foot values and often the lowest offer wins. CLT manufacturers are then subcontractors of the general contractor, which
leaves little room for collaboration with the architect or planner. There are other planning processes like CMGC (construction – management – general contractor) or DDB (Develop – Design – Build) which allow for more communication and collaboration between construction and design, but these are still used very rarely.

HISTORY & TRADITION – Since the Original Market has a tradition of building massive, mineral massive building materials have traditionally been predominant. Moreover, in the alpine region, above ground floors of historic houses have traditionally been built out of an early form of mass timber, by stacking solid square wood blocks, similar to log cabins. Every project tends to be very individual and customer specific and the level of design is high. The saw mill industry is therefore very flexible. They can produce pretty much any dimension without charging a significant premium for it. In North America on the other hand, all-wood lightweight construction types like timber-framing and light-frame construction have a long tradition for single-family homes and also larger multi-story structures. These systems are highly standardized which makes it possible to mass produce on a very large scale. Consequently, the North American wood supply very much relies on standard dimensions. Everything beyond that is associated with higher costs.

ii - Opportunities for CLT in OM and NA

Market Opportunities for CLT can manifest themselves in many different ways. They can be political, economic, social, and more in nature. The topics discussed here are external to the manufacturer and are considered to have a beneficial influence on the development and growth of CLT in the Original and North American market.

META DRIVERS – On a meta level, there are a few global issues that are identified to favor a beneficial market environment for CLT. The first one, is that overpopulation & migration
are increasing worldwide. CLT can create living space very fast. More importantly its good strength-to-weight ratio, makes it possible to take densification of urban landscapes to the next level, by allowing construction of more stories and therefore more housing units on a weak plot of land or on top of existing structures as an extension. Other meta issues are, a growing global scarcity of resources and a need for preserving the global environment. CLT is made from wood and if managed sustainably, forests can provide a renewable and continuous supply of it. Despite recent political events, there is an increasing awareness for climate change in North America. Also, the volume of wood in CLT buildings acts as a CO₂ storage unit, which contributes to balancing the high concentration of greenhouse gases in the atmosphere. After all, the cornerstone of these meta opportunities are the technical characteristics of CLT that make it very versatile and applicable. CLT construction is very fast, clean, quiet and safe, due to the high degree of prefabrication and the simplicity of installation, it can even be disassembled after its time of use. Also, CLT is very light, while still having good structural performance. Further, its fire performance is very predictable due to the massive nature and the seismic resistance is very good because of the high stiffness which is a result of the cross lamination of solid boards. In addition, it is a sustainable or “green” product that provides many additional values that are increasingly requested by today’s society.

APPLICATIONS – CLT is very versatile. It can be used for: public buildings, schools, gyms, hospitals, hotels, apartment buildings, office space, industrial buildings, high-rises, multi-family housing, single-family homes, boutique projects (beautiful buildings), tornado shelters, wind turbines, bridges, etc. Also, usages as T-beams, plate-beams or free-forms, e.g., in artwork projects can be realized. Basically, anywhere where concrete is used above ground, CLT can be used too. Experts hope that the industry thinks about new possibilities beyond what is done today. An additional, often-overlooked application for CLT are crane
or access mats. It can be used to build temporary roads on otherwise inaccessible terrain, without overly impacting the landscape. After their use, they are collected and reused as long as they maintain their structural integrity. Due to the cross-lamination, CLT remains undamaged considerably longer than, for example, conventional non-laminated hardwood mats. Also, CLT panels are much lighter, which makes the transport more efficient. The oil and utility industries, as well as forestry operations in North America use a huge amount of access mats which provides an opportunity for large production volumes of CLT. In the OM, industrial CLT is also used, but on a smaller scale. FEA (2017) claims, that the CLT access mat market in North America is growing much more rapidly than architectural CLT. According to their study, North America consumes 45,000 m³ of CLT for buildings, whereas access mats consume 118,000 m³, which is only about 3% of the potential market for access mats.

MARKET POTENTIAL – The potential for CLT in North America is huge. Especially projects that can be repeated on a large scale, promise great demand. If McDonalds, for example, decided to make even a canopy for their restaurants out of CLT, or if an insurance company would promote discounts for customers who have a CLT garage in tornado-prone areas, very large volumes could be demanded. Even modular single-family housing could find large-scale application for CLT, due to the high degree of prefabrication. All this is further driven by a huge excitement around CLT and mass timber in North America. The current dynamic is much bigger than it was in the original market in the beginning. The Mass Timber Conference in Portland, Oregon, for example, had almost twice the number of attendees in 2017 than the year before, and the governor of Oregon invited CLT experts from North America and Europe to a Summit on mass timber in Portland. Moreover, the National Building Museum in Washington D.C. held a year-long exhibition (until September 2017) called “Timber City”, where modern wood construction techniques like CLT are explained to the interested public.
SUPPORT FRAMEWORKS – By now, North America has a number of support structure in place. In 2011, a standard for CLT (PRG320 APA/ANSI) has been created, and the International Building Code (IBC) of 2015 in the US (must be adopted by every state individually), prescriptively allows mass timber and CLT. In Quebec, Canada, the office of the local building code, the RBQ (Régie du bâtiment du Québec), even made an official design guide for mass timber projects up to 13 stories, making the code approval process much easier and faster. A lot of testing had to be done by the CLT and mass timber industry to achieve that. Besides that, a “CLT Handbook” was created by FPInnovations in Canada which is a comprehensive guide on how to build with CLT. The US and Canadian governments also support mass timber construction. The USDA (United States Department of Agriculture) subsidized new mass timber buildings and manufacturing facilities, the Washington government builds modular classrooms in CLT and in BC (British Columbia), the “Wood First Act” obliges to consider wood as an alternative in the publicly tender process. Besides, there is FPInnovations, which is a partially publicly funded institution, aimed at promoting and advancing wood construction. The majority of this governmental support comes from the forestry side, because the North American forest industry deals with many problems related to forest densification and extensive undergrowth, which increase the amount of fuel for wildfires and make individual trees weaker and more vulnerable to diseases. CLT can make use of smaller diameter trees and potentially alleviate some of these issues. Experts estimate that for those reasons, governmental support will probably be available for some time into the future. All these support frameworks help the whole industry and codes and standards even take some responsibility off architects, engineers, and builders. Before 2015, Mallo & Espinosa (2014), found, that the fact that CLT was missing in the IBC, was the main barrier to the adoption of CLT in the US.
HISTORY & TRADITION – The fact that wood and massive construction are deeply embedded in the building tradition in the Original Market are a great advantage for CLT. There is a foundation of expertise on the manufacturing side. Further, universities, colleges, apprenticeships and even special technical high-schools provide wood education and training to professionals like manufacturers, carpenters, builders, engineers, architects, etc. These institutions also help growing and advancing knowledge about wood construction. North Americans on the other hand, are very accustomed to living in single-family and multi-story buildings made from wood. Mallo (2014), additionally discovered, that the adoption of CLT is more likely to happen in areas within the US, where wood construction has a strong tradition.

iii - Threats for CLT in OM and NA

Apart from prospects, markets also face hurdles and challenges that can prevent a product from growing. In this section, different threat for CLT in the Original Market and North America, that have their roots external to manufacturers, are described. Understanding these threats is a valuable first step to advance the market and industry.

PREJUDICES – There are existing preconceptions within markets that have a negative influence on the perception of wood as a building material. The first and most prevalent one is: Wood burns. Therefore, people tend to distrust timber, because they do not want their buildings to be combustible. This can be addressed by explaining that mass timber and CLT are safe because they burn very slow and predictable. In North America in particular, there is another common concern around the environmental aspect of mass timber. The general public, thinks, that the increased usage of wood will harm the forest. All they can observe is that trees are cut down. The discussion around preserving the spotted owl in federal forests in the 1990s on the west coast, was a good example of how strong these beliefs are and
how much damage they can do to the forest industry. A third common discussion are VOC (volatile organic compound) emissions, especially around formaldehyde. Wood glues can contain this chemical, which is categorized carcinogenic by the World Health Organization. Even wood itself emits traces of formaldehyde. However, there are formaldehyde-free glue systems available and CLT made with Polyurethane adhesive (PUR) for example still lies below the maximum permitted emission values.

CODES & CERTIFICATIONS – There are certifications that may appease public concerns, but especially in North America they are not always beneficial for the wood industry. For example, the FSC (Forest Stewardship Council) provides certification and labeling for responsible forest management and the related chain-of-custody. In North America, it can be hard to implement it, because tracing lumber from the forest to the end-use can be costly and hard to do. This is why the percentage of certifications in the industry still is low. Further, architects and engineers in NA have the perception, that only certified wood is sustainable, a thinking that was greatly influenced by the LEED building certification (Leadership in Energy and Environmental Design). Some informants said, LEED tends to discriminate uncertified wood, whereas Environmental Product Declarations (EDPs) can provide a more comprehensive examination and show different results. Apart from that, the presence of CLT in the IBC of 2015 in North America needs improvements. The current safety mechanisms around CLT in the code are very conservative, which limits mass timber design and makes CLT less efficient and less cost-effective. The industry needs to convince building officials that mass timber is trustworthy, reliable and safe. Also, every state must adopt the IBC, which not all have done yet. Apart from that, there is another threat in the Original Market. Throughout Europe, there is no uniform, manufacturer-independent product standard for CLT, like in NA. Experts say, that this is a big issue for the growth of the CLT industry there. Every manufacturer has different panel sizes, thicknesses and even
mechanical properties. Standardization would make it much easier for builders, architects, engineers and virtually everybody to work with CLT, especially the public bidding process would be more accessible. Experts conclude, that, the medium-term growth of CLT is harmed by the missing standard and that it is only a matter of time until a standard is implemented in the OM.

SOCIAL DYNAMICS – Another phenomenon in North America is that nobody wants to take the risk of being first. Especially contractors are careful. Sub-contractors find it hard to bid on installation and estimate how much time and labor is needed. Some of the individuals in North America, especially in Canada, that are already on board the CLT train, have emigrated from the Original Market or have been educated there. In this context, the very different nature of CLT not only provides technical advantages, but also creates a higher threshold for the implementation in new markets. Once contractors and builders pass the initial phase of uncertainty and adoption, they seem to really like the benefits CLT brings to a building site. Designers like architects and engineers have a similar learning curve. Further experts take the current excitement around CLT and mass timber in NA with a grain of salt because what is really needed in this stage of the market development are actions that follow the many words. Even though the demand for mass timber is growing, it does not match the excitement and is not very stable yet.

EDUCATION & SKILL – In contrast to the Original Market, wood education in North America is very limited. This is a substantial problem for the implementation of CLT and mass timber. No education means no skilled labor, which in turn means no one knows how to work with CLT. The easiest starting point for new wood education is academia. Thus, new programs for wood construction technologies at universities are urgently needed in North America. Beyond that, there are universities in the Original Market that teach in English language and
have comparably low costs of tuition. NA architects and engineers traditionally receive very limited education on wood construction throughout their careers, which extremely limits them in planning and designing with CLT and mass timber. Information about installation of CLT on site, could be provided through a step-by-step guide or catalog. If connections, procedures and tools for CLT installation were standardized, they could be included. CNC fabrication of panels is another area where more expertise is needed in NA. Pei et al. (2016) describe that a more fundamental educational infrastructure around timber engineering is missing in the US. They say, that there have been some outreach seminars and short courses at the professional level, but higher education is lacking options. Mallo & Espinoza (2014) also concluded that the lack of education is a barrier to the adoption of CLT in the US. They further found that architects tend to be more open to wood-based construction materials, whereas engineers prefer to use concrete and steel, because of their education.

DESIGN PROCESS – The current design processes in North America are very stiff and old-fashioned. One process is the Design-Bid-Build process, which is very popular because it is seen as a tool to control the price of a project. The biggest challenge for CLT, using this process, is that manufacturers have to bid on a pre-made design, which often forces a non-efficient use of CLT and mass timber. As a result, CLT can have problems being cost-competitive with conventional building materials. Another related issue is that decisions are mostly based on cost-per-square-foot calculations and CLT is most cost-efficient if viewed as a whole system. These resulting miscalculations can make CLT less competitive. Another aspect is that trades often plan ahead very little and try to figure out things on the construction site. With CLT this is another problem, because customizing panels on site is much less efficient that on a CNC machine beforehand.
EFFICIENCY & KNOW-HOW – According to experts, the mass timber construction industry in NA is not yet using its full potential of efficiency and know-how. One reason for that, is the small number of existing manufacturers. Even though some European manufacturers offer their products in North America, there is comparably little competition on the market, allowing manufacturers to be less than highly efficient. Therefore, CLT overall is still more expensive in North America. There is existing knowledge and skill in more experienced CLT markets that can be learned from, but the North American industry tends to ignore these existing sources of knowledge. Many mistakes and experiences would not need to be repeated in NA if cooperation was pursued. This could expedite the implementation of CLT. Most publications around CLT and mass timber in the OM are also available in English and many European manufacturers are willing to start collaborations internationally (some are even actively looking for partners).

RAW MATERIAL – In North America, the most abundant raw material for CLT is 2x4s, 2x6s and 2x8s. These dimensions are traditionally intended for light-frame-construction and usually produced at 19% moisture content. CLT production however is required by the PRG320 standard to use material with 13%, ±3%. Hence, every manufacturer must condition the raw lumber, or find sources of dryer material, which is both associated with increases in cost. The second concern expressed by experts, was the fact that only using two-inch material limits CLT production to panel thicknesses of 3, 5, 7, or 9 times two inches. This in turn limits the structural design and can make CLT less efficient and less cost-competitive. Some manufacturers already use thinner raw material in combination, but availability of thinner stock may be a challenge. Further, overall supply of raw material might become a problem in the mid-term future. When the demand for CLT grows, raw material prices are likely to increase. Also, the usability of forests is a big challenge. In the OM, forests are becoming more subdivided, which results in a higher percentage of unusable timber
volume. A similar problem occurs in NA, where timber harvest from federal lands is very limited. Another threat for the CLT industry, is the volatility of lumber prices in NA and OM. This makes it hard for manufacturers to price their products in the bidding phase of a project, so when it is time to produce a building, costs might be totally different. Since the raw material accounts for about 60-80% of the price of CLT, this can change the final price drastically. Customers do not like this insecurity. However, if a manufacturer is integrated vertically and has a saw mill or even a forestry operation, this becomes less of a problem because price fluctuations can be controlled internally.

iv - Strengths of CLT manufacturers in OM and NA

Due to the novelty of the product and the unique nature of the material itself, manufacturers that produce CLT are a particularly diverse crowd. Every company has its own strategies and ways of achieving their goals. Within this section, some aspects are provided regarding strengths different CLT manufacturers have and how they affect their operations.

VERTICAL INTEGRATION – Vertical integration implies that a company combines more than one production step under one single ownership or business. In the case of CLT, this can mean that a company produces CLT panels and sawn timber, or even has its own forestry operation. The furthest possible upstream step would be owning timber lands. In the Original Market, almost all larger CLT companies are integrated vertically. Manufacturers explained that the reason for this is, that many of them were saw mill operations already, before they got into CLT. In North America, about half of all currently existing operations have vertical integration, the other half buys raw material on the open market. Vertical integration can also bring certain benefits like consistent pricing and higher purchasing flexibility. Some large CLT manufacturers in the OM have annual cost sheets for CLT. During the financial crisis in 2007 and 2008, manufacturers in the OM that were integrated vertically
showed better overall performance, whereas companies that only focused on the CLT production step were faced serious struggles.

BROAD PORTFOLIO – Many companies that manufacture CLT also manufacture other structural timber products, both in the Original Market and the North American market. By having a broad portfolio, a company can provide many components that are needed within a project from one source. Glulam is most commonly offered along with CLT. In fact, most larger glulam manufacturers in the OM now also produce CLT. But also, products like solid structural timber, DUO- and TRIO-beams are often manufactured by the same firm. Some companies say that an extensive product portfolio is their biggest strength. One or two even have steel shops in-house, that make connectors for CLT and mass timber construction. The more comprehensive a portfolio is, the more efficient a company can be in the planning and design of a project, which can further result in competitive advantage.

ADDITIONAL SERVICES – It is very important for CLT manufacturers to offer additional services beyond the material itself. One of the reasons for that is that CLT is nearly always custom made. Every panel is made for a specific project and a specific purpose. Therefore, the raw panels must be customized, usually with a CNC machine which is integrated in the production line. Often, companies also offer different surface qualities. The most important additional service however is related to the planning process of a project. Almost all companies have some kind of technical planning expertise. This can range from simple design assist services like the planning of technical details and panel sizing up to full scale structural design departments that can do the full planning process for an entire project. Another option is to have very close partners or affiliated companies that provide these services. No matter how the actual operational structure looks, providing additional services to the customer is a very important asset for a CLT manufacturer to have. Muszynski et al.
(2017) found that manufacturers see their additional services as the second most important competitive advantage, after high quality.

EFFICIENT PRODUCTION – Especially in the Original Market, CLT manufacturers have a high focus on efficiency in production. Based on the long local history, this is still highly needed because the density of producers in OM is very high. If a production line is too inefficient, the operation is simply not competitive. Because of that, manufacturers constantly try to improve their operations and systems. The resulting high standards and the drive for development and perfection brings new production technologies as well as product improvements. One company, for example, starts customization at the layup (further explained in section V.c.xiv.), whereas another company produces small size commodity-type panels that carpenters can handle and machine themselves. This diversity of operations is a great source of innovation and efficiency and an important strength of the industry.

v - Weaknesses of CLT manufacturers in OM and NA

The current CLT industry is comprised of companies in many different stages. Some of them recently entered the CLT business and are still in the learning phase, others have been in operation for almost two decades and therefore have considerable experience. No matter how old a company is, there is always something that can be improved. These identified weaknesses are explained in this section.

TRANSPORTATION – The transportation of CLT needs to be very efficient in a successful business model. One of the reasons for that is that just-in-time delivery is highly important on a CLT construction site. The whole installation team cannot be waiting for a load of CLT to arrive, that would not be cost-efficient. This aspect becomes even more important in North America, because distances can be very far. The most reliable method of
transportation in NA tends to be trucking, while trains can be unpredictable. However, truck drivers in NA are not yet used to just-in-time delivery and strict delivery times. Possible solutions to increase the efficiency of transportation would be to establish smaller, more local productions, as well as being integrated vertically, so that only the final product has to be shipped and the raw material can be sourced locally. Manufacturers must carefully plan their strategies around transportation. Inefficiency of transportation can be a significant weakness for CLT manufacturers.

INDUSTRY COOPERATION – Another aspect about the CLT industry in the Original Market, especially in Austria, is concerned with the relationships between individual manufacturers. They say that there is very little cooperation in the industry. There is a trend toward CLT producers seeing other CLT manufacturers as their main competition, even though, right now, the product is in high demand which provides enough opportunity for all companies. Experts emphasize that for the growth and success of CLT as a whole, the most significant competition is other massive building materials like concrete, brick and even steel. Further, these other materials have much stronger lobbies than wood in general. Taking this further, there are individual companies, especially in Austria, that tend to sell their products very cheap. Experts say that the current market could support higher prices for all manufacturers within. Considering those factors, it can be considered a strong weakness for the growth of CLT as a whole and the development of every single manufacturer, if cooperation with the industry is not part of a company’s strategies. A stronger CLT and mass timber lobby is greatly needed.
c - LESSONS LEARNED

Over the years, the CLT industry and all its associated individuals acquired a great deal of expertise and knowledge. Based on the findings of this research, a list of lessons that can be learned from the rich history of CLT was identified. This part of the results is generally sorted following the significance factors, which were explained in section IV.g., starting with the most significant information block at the beginning. Following graphic shows this section of the overall research framework:

![Figure 14: Results stage 2: Lessons Learned](image)

### i - Wood Education

Experts mutually agree that it is highly important, not only for CLT but for mass timber construction as a whole, to foster education. However, making people more aware is not enough. What is really needed, is creating skilled labor. Education is an entry point for new professionals to enter the industry. Aside from that, the related research also increases the amount of known knowledge and foster new developments.

It is very important to especially focus education on the groups of professionals that work with CLT. First of all, architects must be instructed on how to design and plan with CLT. As mentioned briefly before, it is crucial to not only talk about the benefits and advantages of CLT, but about the whole package, including vulnerabilities and weaknesses. Only if architects know CLT and its qualities inside-out, can they design buildings efficiently and
sustainably. Architects have the power to choose one building material over another, so the more they are comfortable with CLT, the more demand can be created. In the Original Market, architects were the biggest multiplicator in the beginning. They were almost the only people demanding CLT, whereas the wood construction industry was afraid and cautious. Experts know: "If you can’t convince architects, you don’t have projects!"

The second key group are engineers. They are the ones that must make a CLT project work. They have to fully understand the properties and characteristics of CLT and wood in general in order to plan efficiently. For example, if an engineer is educated poorly, he might plan too much on the safe side and use panels that are unnecessarily thick for a certain application. This in turn can make a CLT building more expensive and possibly no longer cost-competitive. The more knowledge an engineer has about wood, the more he can increase the efficiency, flexibility and longevity of a project. Experts in North America see a tendency that most architects are initially excited and engineers rather skeptical about CLT.

After the planning phase, a mass timber structure must be installed as well. This is another area, that requires trained labor. In the Original Market, carpenters find it very easy to adapt to CLT, but in North America this expertise is missing. General contractors and sub-contractors are generally used to concrete, steel and frame construction. CLT and mass timber, however, requires a different set of tools. Contractors that have done it say that it is very straightforward and simple to install a CLT building. Despite that, the initial reactions of contractors that are new to it often are skepticism and uncertainty. The best way to teach someone about CLT installation is by doing it. Repetition fosters expertise. As mentioned earlier, poorly educated contractors tend to charge overestimated prices and therefore make a building less cost-competitive. An expert said, that the installation team of the Albina
Yard project in Portland, for example, needed about 60% less time for the installation than initially estimated.

Another aspect of wood education is communication and cooperation. It is of high importance to connect the academic environment with the industry. This has been done in the Original Market for many years and also has its place already in North America. However, there is much more that can be done. A few ideas, primarily from the Original Market are: joint academic research projects with the industry, field trips to local and international CLT hotspots, installation demo days, idea competitions, architectural competitions around new technologies, pilot projects, prototypes, seminars, lectures and other kinds of knowledge transfer activities. Further, it is crucial to find new and important research topics through discussion with the industry, looking at what is needed first and then trying to find a solution. It can be an unnecessary waste of resources, if time and money are spent on irrelevant research topics, because of a lack of communication.

The last focus of wood education is on the general perception of CLT and mass timber products. As explained before, there is a big existing misconception in North America about the sustainability of wood as a building material. The general public and also developers, architects and engineers tend to think that wood is less sustainable than concrete and steel. It is very important to aim educational efforts at this issue by providing facts, numbers and studies, in order to address people's reasoning, rather than their beliefs. There are institutions in NA that are actively trying to change this perception, but more could be done.

The importance of educating architects about CLT was also found by Mallo & Espinoza (2014). Their study identified, that the missing availability of education about CLT creates a barrier for the adoption of CLT in the US.
Experts repeatedly emphasized, that CLT is more than yet another construction material. It is a building system that provides many benefits as a whole. One of those benefits is installation, which is fast, safe, clean and quiet, and therefore very efficient and cost-effective. In installation, this is where the biggest cost advantage of CLT lies. In order to achieve this high efficiency, planning and design must look beyond the panel to the holistic building.

At this stage of the development of CLT the existing concepts are still immature and have room for improvement. According to experts, it is important to constantly keep developing and enhancing so that the degree of efficiency can be increased. Even though CLT buildings are practically always custom-made, it would be a great benefit to have existing concepts to rely on as a foundation for a new specific design. Experts even go as far to request that these methods and techniques for CLT structures should be standardized. This would make it considerably easier for the whole industry to work with the product. Planning, design and installation would benefit from standardized solutions for CLT construction. Standards and certifications provide trust and credibility to the customer. Correspondingly, they would assure CLT customers like developers, owners and investors, because they can see that it works. A catalog, (something like CLT handbook or BSP Handbuch), including all standardized details and methods could be established. Other sectors of the construction industry, like light-frame, or concrete construction, already have this level of standardization.

The Brock Commons building, an 18-story student residence in Vancouver, BC, was built in 9.5 weeks. This means, that the construction team was able to install two stories per week, which is considerably faster than in concrete. Taking the holistic building concept into account in the bidding and pricing stage, CLT can be not only faster, but also cheaper. In North America, it is hard to convince architects and especially developers of this, since
traditional planning processes tend to work with generic price factors and cost-per-square-foot rates, rather than comprehensive cost considerations. It is a big challenge to educate developers about the importance of looking at the holistic building concept.

iii - Holistic Design

Since CLT is a concept, not only a material, the planning process must be adapted accordingly. It is very important, that all the different professions that are involved in the planning process of a CLT project work and communicate well together. Good cooperation is needed to keep the whole process of CLT construction efficient and fast which is key for CLT to being able to successfully compete.

Partly due to the high degree of prefabrication and partly due to the different nature of CLT in general, the design process must start very early. According to experts, it can be very difficult and inefficient to incorporate CLT into a project that has not been planned in CLT from the beginning. This has a lot to do with the fact that CLT is a panel. This changes the way forces are conducted through a structure and therefore changes the shape of almost all load-bearing members. In addition, CLT manufacturers produce different products with different properties and dimensions. So, experts conclude: "With CLT, working with the manufacturer from the beginning, is really important!". If the manufacturer is not known early, or changes through the process, all plans and 3D models must be changed to incorporate the new panel dimensions and performance characteristics, even structural calculations must be corrected. Engineers can try to create an initial design so that CLT of several different manufacturers can be integrated later with less effort, but it still results in significant extra work that effects the overall efficiency of a project. All this makes it very important to have a good design team where architects, engineers, builders and manufacturers all work together very early in the design phase.
Experts say with CLT, more time must be spent on the planning phase, so that the construction phase can be expedited. The more planning effort is invested beforehand, the higher the degree of prefabrication, and the faster the installation. Consequently, time and cost efficiency can be increased. In the Original Market, this approach can be pursued much easier than in North America, due to the existing planning traditions. Another aspect of planning practices, is that in North America the trades often are provided with little planning guidance, so that they have to figure things out on site. Also, developers and owners can request changes in the design on site, throughout the construction phase. When building with CLT, this really affects the efficiency of a project negatively. The problem is not so much that the panels cannot physically be changed on site, but that the additional amount of labor increases the installation costs significantly. This would take away the benefit of a quick assembly. Therefore, owners must be made aware, that design process and installation have to be clearly time separated.

Experts in North America see CLT and mass timber as a potential catalyst for modernizing the old-fashioned structures of the existing planning processes in their market. It could favor a higher degree of collaboration and a more comprehensive planning approach. Overall, the efficiency of the construction industry could be increased.

iv - Wood & Water

If wood is exposed to moisture, the risk of decay becomes disproportionally higher. Initially, this might sound like common sense, especially for people that work in wood-related professions or industries. However, this very fact is currently not sufficiently considered in the planning and design of mass timber construction. Designers tend to use conventional details and designs, which are often copied from other construction types, and use them in CLT and mass timber buildings. This can be a big mistake. Experts emphasize the importance
of understanding and working with the weaknesses of wood construction. They explain: "The biggest enemy of wood is water!", and further add on: "Other building materials have other enemies, steel can fail without warning if exposed to high temperatures and concrete even cures with water!".

On the other hand, wood does not decay instantly. It has the ability to absorb, but also desorb moisture. So, if a CLT structure gets for example rained on in the construction phase, it is not the end of the world, as long as it can dry out again. The real danger is a continuous high level of moisture. If a building has a water leak for example, and the effected CLT stays wet, these panels will develop serious damage. Therefore, it is crucial to react fast, if a water issue is encountered in a wood structure. This, is crucial for the longevity of a timber building.

In the Original Market there have been cases, where CLT and mass timber buildings were damaged by having a small water leak or some other kind of moisture trap. Water damage in CLT can be of special concern because these panels are very large load bearing members. If they are compromised, the structural integrity of a building can be at risk and on top of that, the following repair work can be very complex and expensive. The sooner an issue is detected, the less effort it takes to fix it.

**v - Building Services**

Experts in the Original Market say, that "the only big weakness" that is left in the development of CLT and mass timber construction, are water-related building services. This is also highly related to the previous topic about the relationship between wood and water. Accordingly, new optimized solutions for building services in CLT and mass timber buildings are needed.
As mentioned before, it is currently common practice to use the same details and designs that were developed for technologies like concrete, brick or steel, in CLT and mass timber projects. By doing this, the biggest vulnerability of wood is ignored. Wood decays when wet. If a water pipe is routed within or underneath the screed of a floor construction, as usual in conventional construction, and it starts leaking, water invades. Since there is material all around, it might take some time until the surrounding structure is saturated and the issue becomes visible on the surface. If it takes a few months to notice this issue, a building made from concrete can be fixed mostly by stopping the leak and drying out the structure. If it takes that long in a CLT building, the same issue will have done a lot more damage and also structural components are likely to need costly replacement. This is why it is very important to develop and use building services that are adequate for wood construction so that any kind of abnormal moisture concentration can be detected right away and damage be prevented before it happens. For that reason, experts in the Original Market ultimately demand: “No single water-carrying pipe should be routed inside of the floor construction. No fresh water, no warm water, no coils for floor heating. All water-carrying pipes have to be accessible!”.

A lot more research must be done on building services in mass timber construction. Not only because of the potential issues that are associated with conventional solutions, but also because the amount of technology built into a structure is increasing in general. Experts estimate, that in a modern building, the building services can account for up to one third of the overall building cost. That alone would give reason to focus extensive research efforts on building services. The Graz University of Technology, for example, is starting to widen their focus and expertise around those topics. However, it is very important again to conduct research in a way that the industry can relate to, so that they can implement it. One potential solution to the water issue in mass timber buildings, is using moisture detectors. They could
function just like smoke detectors and sound an alarm when an abnormally high concentration of moisture is detected in a building. This would drastically shorten the response time to a water leak or other moisture issues.

Another aspect of building services in CLT building is that the nature of the product, paired with prefabrication, allows following trades like electricians, plumbers, and building service technicians to work very efficiently. It is, for example significantly easier, quicker, cleaner, quieter and safer to drill a screw into a CLT ceiling than it is in a concrete slab. Also, if wall ducts and other routing channels were pre-routed on a CNC machine, all that the following trades must do is assemble their products into the larger structure. Thus, the labor on site can be reduced drastically. As the industry grows, experts hope to see standardization for these interior construction techniques and solutions so that builders can rely on a set of existing knowledge and can be even more efficient and confident.

Tall Wood Illusion

There is an unofficial competition within the global CLT and mass timber scene about building tall in wood. The media often report on the latest development in wood construction and big plans for the future. However, experts have mixed feelings about the tall wood hype.

First of all, the extensive publicity and reach that news about tall buildings in wood are generating is a benefit for the industry. Many people get excited about these projects and even the general public occasionally shows interest. It creates excitement to watch taller and taller buildings go up and it also pushes the limits of what is possible with state-of-the-art wood construction. However, the global level of excitement around CLT and mass timber is already very high, and the real drivers that are needed to advance the industry at this point
are: a reliable and increasing demand, higher efficiency, and a good market penetration through a diverse portfolio and large volumes of CLT panels. Most tall wood projects though do not really provide these hard benefits. They require a lot of planning and preparation. Not only the technology must be evolved, but also a great amount of time, energy and money are spent on additional work like political negotiations, getting special building permits, and testing of new technical solution. After all, tall lighthouse projects that are made to shine, are not cost-effective at all. Even tall wood buildings that have the objective to be as efficient as possible are hardly profitable. The installation on the other hand can be very fast and simple still, especially if repetitive floor plans are used. 

A term that experts, especially in North America, mentioned frequently along those lines, is: "the mid-rise-gap". This refers to a phenomenon, around the efficiency of building materials for certain applications. In Canada and the US, it is only allowed to build in wood frame construction up to about 5-6 stories, depending on regional codes. Everything higher therefore has to be built in concrete or steel. However, experts say that concrete is not very efficient below about 10 stories. So, the area between 6-10 stories, is called the mid-rise-gap. This circumstance is a great opportunity for CLT and mass timber construction because in current state-of-the-art they are very efficient in that particular height range. In addition, the mid-rise market is much bigger and has much more demand than the high-rise market for tall wood buildings. According to experts, only approximately 10% of all apartment buildings in the US have more than 12 stories. As a conclusion, the “sweet spot” in the height discussion for CLT construction in North America, lies in the midrise gap. Some extend this number down to four and other predict it to grow up to as high as twelve. In the end, a conservative estimate is 6-10, and an optimistic estimate is 4-12 stories, of mostly residential, office and mixed-use projects. In addition, the NA commercial building sector is very large and has a lot of potential for CLT and mass timber. Applications like warehouses, furniture
stores, retail stores, grocery stores, large schools, hotels and so on are great uses for this technology.

Considering all of these factors, global research efforts are needed to focus on supporting and advancing the entire industry, not only the small, tall wood piece of the pie. Further, there is much more R&D work needed to make tall timber buildings efficient and sustainable. If, conventional building service designs are used and a water leak causes damage on the 18th floor of a CLT structure, the repair work is yet much more difficult and expensive than in a single-family home. Experts would also like to see new concepts that are considering potential repairs in advance, so that structural wood components can be replaced much more efficiently, if necessary. Tall wood projects also need to be planned and designed holistically.

Crespell & Gagnon (2010), state in their CLT primer, that CLT is costs-competitive in about two thirds of the non-residential market. However, they further say that CLT is most competitive in the mid-rise segment of the US market.

vii - Hybrid Systems

Another important lesson learned, is to not be afraid of using CLT in combination with other materials. Every building product has its own set of advantages and disadvantages. By designing a hybrid system in a thoughtful way, the individual strengths can be magnified, and the weaknesses mitigated, which can drastically increase the efficiency of a structure. For CLT, a high efficiency in turn is key for being cost-competitive.

The possibilities of hybrid structures are only limited by the imagination of the designer. Currently, concrete is the most used material in combination with CLT and mass timber,
followed by steel. A common combination, is to use a concrete topping on a horizontal CLT panel. When connecting the two layers in a structurally sound way, the final structural component can not only span longer distances, but also has better performance regarding sound and vibration. When combining different elements, it is very important to be aware of what they can do so that every material is used where it makes sense. Also, hybrids of different wood products like CLT, glulam, LVL, PSL, and so on, make a lot of sense. Sometimes a beam or a post is simply the structurally better solution, sometimes a panel can do much more, and occasionally a panel that is reinforced with ribs can give the most efficient result. It all depends on the specific application within a building.

However, there still is a lot of room for new developments and ideas. Academic as well as industry research is greatly needed to find new combinations, systems and uses. A very crucial aspect of hybrid systems are the connections between the individual components. The more simple and effective the links are, the more efficient the whole solution can be. If the connectors are too expensive or complicated, the whole idea might be fruitless.

Experts say: "Hybrid solutions have much more potential!". Advancement could for example start with the layup, by introducing carbon fibers into a CLT panel, or including an electroconductive layer that can be used as electrical wiring or wall heating. The potential is endless and there is a lot more to be invented. Some manufacturers already work towards that and supplement layers of regular lamellae with different wood composites. Finally, new hybrid systems could also be certified through testing (strength, fire, sounds, ...), so that designers and builders can use them easily and freely, which is crucial for those inventions to be adopted.
Prefabrication and Automatization

The fact that CLT is a panel that can easily be machined and transported carries a lot of potential. This unique combination of qualities makes it possible to produce housing fast and efficient without the need of skilled labor. Experts recognize that this makes CLT very exceptional, since no other building product can provide this whole package on such a large scale. Moreover, all this directly complies with the meta drivers mentioned in section VI.b.ii and also provides a potential opportunity to modernize the entire construction industry.

Compared to other building technologies, the degree of prefabrication is very high in CLT construction. Common practice in the Original Market and also in North America, is to CNC fabricate every single panel of a building beforehand, and off-site. This, in turn, requires a high degree of preliminary planning, as explained in section VI.c.iii. Usually windows, doors, and connections between panels are prefabricated, as well as electrical wire and water pipe routings, sockets, switches, and other preparations for interior construction. The assembly is then mostly done on the building site. This changes the traditional approach to construction and turns a construction site into an assembly or installation site.

However, the state-of-the-art in prefabrication is already taking it much further. Instead of transporting individual panels, entire cubicles and modules can be preassembled in the factory. Modularization makes it even possible to preinstall interior construction and facades, so that an installation site can consequently become a mere delivery site. There are projects that have been done where large CLT modules were highly prefabricated and stacked on top of each other to build large multi-story structures. The more is done in advance, the more efficient is the whole construction process, and consequently the more cost-competitive a CLT project can be.
To bring in an additional aspect, looking at other industries like the automotive or computer sectors shows that modern production standards are taking efficiency to an even higher level. The human component is eliminated as much as possible so that manufacturing becomes highly predictable and reliable. There are no Friday cars anymore. The construction industry on the other hand has not followed this trend. However, experts think that CLT can provide an opportunity to change that, and introduce not only prefabrication, but also automatization to the global building industry. Modularization has been done with CLT for quite some time already, but these projects were comparably rare. Besides that, CLT, is almost entirely custom produced, where every single panel is made for an exact application in a specific project. There is no mass production of panels. Be that as it may, experts further see that automatization cold potentially allow mass production of CLT, however, not by selling panel-by-panel, but rather module-by-module. Customization could then still be retained by offering a few box types and altering certain features of the interior of a module, similar to car models and extras in the automotive industry. Supporting that, there are at least two existing companies in the industry that are, at present, working on establishing large-scale manufacturing facilities that are aiming for a very high degree of efficiency, by maximizing prefabrication and automatization. They plan to mass-produce modularized CLT housing. If one of them succeeds, this concept will spread globally.

A study from FEA (2017) also addresses this potential. They predict, that decreasing skill levels and increasing productivity are keys for the future of the construction industry because affordable housing is in high demand worldwide and skilled labor is hard to find. Further, they estimate that if the CLT industry focuses on automatization and prefabrication it can satisfy those very needs and CLT could grow exponentially.
In comparison to other construction systems, CLT requires a high degree of care and precision. What this means is that everything must be planned and executed thoughtfully and deliberately. This already starts at the design process, where, a building should be firstly planned as a whole, being aware of the whole scope. In addition to that, every detail has to be designed carefully, so that the best possible solution can be found. One thing that experts said multiple times, was: “Do not copy from concrete!” As explained in section VI.c.iv., this is critical to the quality, damage susceptibility and therefore the lifetime of a CLT building. CLT has very different needs and specification than concrete.

Especially important is precision in the manufacturing process. Because the degree of prefabrication is so high, the production tolerances have to be kept very small so that the final system can be assembled easily and in the correct manner. Production procedures also require care. Details like minimizing the time between planer and press, keeping a constant controlled temperature and humidity in the whole manufacturing facility, or having very uniform thicknesses of the individual lamellae, can make a CLT production much more efficient and high quality.

The installation of CLT must be done precisely. The prefabricated elements must be delivered and assembled in the right sequence, using the exact connectors that were defined in the design. In particular, it must be assured, that no water is trapped in a CLT structure in the installation phase. Lastly, the lifetime of a CLT building can be increased, if a structure is well taken care of. Good maintenance starts with as little as being aware of the fact that high moisture concentrations can harm wood.
Establishing New Production Facilities

If someone wants to become a CLT manufacturer there are many aspects to consider. Experts and manufacturers say that two things are especially important. Firstly, having good production know-how is crucial, but also knowing the construction industry within a respective market is absolutely essential. In terms of production know-how, companies that are already in the wood products industry have an edge, especially ones that make glulam. These companies know how to use wood adhesives and how to efficiently laminate boards. Also, they have a finger jointing operation and most likely also some kind of fabrication capability, possibly even a CNC.

Glulam manufacturers that have expanded to produce CLT say it was still challenging. First of all, glulam is often produced as a commodity type product. Even if it is customized, the amount of additional work is not very much and the planning is most often done by someone else. With CLT this is completely different. Every CLT panel that is produced, is a custom-made product and needs to be especially fabricated to the needs of the customer. If a company wants to be competitive, a CNC especially made for panel fabrication is absolutely necessary. An existing CNC in a glulam plant is likely not able to work on panels. In addition, a CLT manufacturer must do a lot of planning work up front. Every project typically has an engineer on board and, the manufacturer must be able to provide pre-static calculations, technical detailing, 3D modeling and design assist and optimization in order to produce efficiently, which in turn is needed to be cost-competitive. Also, logistics are totally different around CLT. Just-in-time-delivery and the right sequence of loading and unloading are necessary skills to have.

Another decision that has to be made, by glulam producer that want to start producing CLT, is if they want to extend their current production, or if they want to invest into a separate
new production line. Experts have a fairly clear answer to that. If the funding is available, a green-field investment is the better choice. This is firstly, because a clean start makes it possible to use state-of-the-art technologies and to design the whole plant professionally and optimized. The resulting manufacturing facility will be much more efficient than a patchwork of old and new, and, as mentioned several times, efficiency is what make a CLT manufacturer cost-competitive. To sum it up, one larger manufacturer said: "If the decision is made to invest, why not invest into a proper production right away?".

Machine producers even offer pre-planned CLT production lines. They can be ordered from a catalog. However, experts also warn about not jumping the gun. Anybody can buy a plant, but launching and running a manufacturing facility successfully is another story. There is a lot of fine tuning to be done and all the aspects that were mentioned two paragraphs earlier must be considered. A potential slow progression for a glulam producer that mostly does commodity production, could be starting to provide additional services. This can especially be a high degree of customization or, even more importantly, planning and engineering capacity. This intermediary step can help to get to know the construction industry and get a grasp of how the customization process works. Once this is second nature, the stretch to manufacturing CLT is no longer big.

**xi - Find Market Entry Points**

In order to build a new market, experts say, it is very important to find an entry point. For CLT, this can be initial applications and usages that are easy and safe, so that market penetration can be increased without taking too much risk. The industry must find niches where CLT can compete successfully by providing superior solutions. It is key to combine novelty with current traditions. It is also good to rely on a great variety of different
applications so that many different customers get to know the product and if one area of the market has difficulties, the others can still support the industry.

Some potential entry points for CLT in North America could be the following: Any type of floors for buildings could be made with CLT panels since they require less fabrication and are therefore more efficient. Also, tornado shelters could be made of CLT. Already in 2008, there have been tests done at Texas Tech University where a European 125mm, 5-ply, CLT panel passed the requirement for this application. Also, for disaster relief after a tornado, tsunami or earthquake could be a good fit for CLT, since the installation is very fast and new homes for victims could be provided in a short time. After CLT showed good results in a blast testing program funded by the U.S. Forest Service and the Softwood Lumber Board, the US department of defense might be another niche. Apart from that, more conventional applications for CLT can be good market entry point. Hotel chains show increasing interest in the product, in particular because of the fast installation times. In addition, commercial construction was mention several times as a very good market for CLT, especially in combination with glulam. Lastly, as mentioned in section VI.c.vi., the mid-rise-gap can become a long-term niche for CLT in NA.

xii - Competitiveness of CLT

Experts and manufacturers know that CLT can successfully compete with other building products if it is done right. As mentioned before, this is highly dependent on efficiency. The material cost for CLT can be a little higher than for concrete construction, but the installation is much more efficient and therefore less expensive. “The efficiency of CLT lies in the technology, not in the material!”. This means that CLT as a whole package can be cost-competitive with concrete and other massive construction types. In addition to that, CLT as a panel, can provide architects with the same geometrical freedom as reinforced concrete.
In fact, qualities like light weight, visual appearance, predictable fire performance and so on, can allow more flexibility in design.

Comparing CLT to steel construction, however, can be less optimistic. First of all, the installation of a steel frame building is similarly fast to CLT and mass timber, because the individual posts, beams and frames are also prefabricated and are assembled on site using cranes. Further, experts say that steel construction is cheaper than mass timber. To sum it up, the real benefit that CLT has against steel is the fact that it is a massive panel and that it is made from renewable resources. Similar to that, competing with light-frame construction has its challenges and CLT is simply more expensive. However, CLT provides much more additional benefit and value and hybrids like light-frame walls and CLT floors, could still be very feasible. This would increase the sound and vibration performance of a ceiling substantially, while increasing the price only marginally.

Manufacturers in North America say that price is the hardest selling point for CLT. They say, that developers mainly care about price and schedule, followed by some degree of quality. Environmental aspects are unfortunately not very valued. However, some owners and investors seem to recognize the advantages that CLT construction brings and are willing to pay a small premium of about 3-7%. For public tender, however, the bottom dollar counts. Furthermore, manufacturers know that the building shell only accounts for about 10-20% of the total building cost. The interior construction is much more expensive. If this is taken into account, CLT and mass timber can make sense again, even if it is more expensive. This is because timber buildings often need less interior decoration work, since people tend to like the appearance of wood as it is.
In addition to that, a study about the “Potential of cross laminated timber in single family residential construction”, by Burback (2016) found, that single-family homes made from CLT are about 21% more expensive as light-frame construction. His conclusion further was, that this price different is enough to prevent CLT from becoming mainstream in single-family residential construction in the US.

R&D is needed

Even though there is an existing industry and superb buildings have successfully been built in CLT, experts think it is fundamentally important to spend extensive efforts on the research and development of new innovative ideas. Concerns like: “There is a missing excitement for R&D.”, or “People don’t think!” were expressed. Beyond the need for R&D, the research focus is even more important. In the current state of CLT globally, there is too little research done on building systems and concepts. Only if CLT can provide complete and efficient solutions as a whole, can it be a competitive alternative to conventional building types. As an example, building services in a CLT building need a lot of innovation and improvement. Currently, research is done both by universities and manufacturers. No matter who investigates, it is important to collaborate.

There is a trend towards using CLT surfaces visually. However, a high-end interior surface on a CLT panel requires a lot of special production know-how. There is for example an ongoing discussion within the industry regarding whether edge-gluing of the lamellae increases the surface quality or not. Once CLT is installed and undergoes changes in moisture content, the individual boards will shrink and swell. Some say, that if you glue the narrow sides, eventually the surface will develop random cracks, so they prefer not to glue them, so that the gap between boards can balance that movement by opening up. The result would be a regular pattern of parallel gap lines. Others say, that modern houses are
very good at controlling the environment within them, so the CLT would not change moisture content drastically and therefore edge-glued surfaces have a better quality and appearance. Apart from this philosophical discussion, there are a lot more ways to improve CLT surfaces. Additional outer layers, or surface treatments for example, are starting to be experimented with. A last topic in this regard, is the transportation, handling and installation of visual surfaces. More research could be done for this aspect.

xiv - Efficient Use of Wood

Another aspect, where experts see increasing research demand, is efficient use of the raw material wood. As explained in section Vi.b.iii., there are concerns that increasing demand for CLT could cause a shortage in wood supply. Therefore, it becomes more pressing to find ways to decrease the overall volume of wood needed to make a specific CLT project. Also, from a sustainability point of view, this is an important topic.

There are two main approaches to saving material in a CLT building. Firstly, the amount of timber that is used to produce a panel in the first place could be reduced. This could be achieved by changing the layup so that the same strength properties are achieved while using less material. An example could be strategically introducing pockets of air into a panel. Another innovation on the manufacturing side that help with that issue is a customized layup. What this means is that all openings like windows doors or other subtracting shapes are not even produced in the first place. There is at least one large existing company that uses such a technology and others are planning to follow. Another method is to produce the whole panel and find appropriate ways to use the cutouts. Research has been done on separating and reintroducing them into the manufacturing of a new panel, or on using the cutouts in non-loadbearing partitioning walls.
The second main approach, is saving material through thoughtful structural design. If, for example, longer spans are needed for a ceiling, it could make more sense to use a thinner CLT panel in combination with glulam ribs, or also a concrete topping, than to simply use a thicker panel. Also, if large window openings are requested by the architectural design, it could make more sense to use glulam girders, rather than cutting out a large percentage of a CLT panel.

**d - CLT FORECAST FOR NORTH AMERICA**

Considering the opportunities for CLT in North America that were explained earlier, there is a solid foundation already in place. Supported by things like the existing standard, or the great excitement around mass timber, the industry will keep growing and developing. Experts estimate, that the demand for CLT is growing and not far from being able to support a larger number of manufacturers. Especially important is the fact that, by the end of 2017, many states will adopt the new IBC of 2015, which includes CLT as a structural system. This makes the process of getting a building permit much easier, which in turn lowers the threshold of building with CLT and therefore has the potential to increase demand.

There are currently several companies strongly considering starting new manufacturing facilities and a few have started to actually work on establishing new plants. In the Original Market, it took about 5-10 years for the big fish to join the pond, whereas smaller pioneers did the work of making their habitat bigger. This trend can also be expected for North America. Once the first large company is on the market, there will be others following shortly. This, in turn, will significantly increase manufacturing standards and consecutively make the whole industry more efficient. Further, this will make CLT more cost-competitive and the market more stable. As noticed before, competition can also increase the efficiency
within a market. In addition to native producers, there are several European manufacturers currently exporting their products to North America. However, experts think that, once local production becomes more efficient, within less than a decade, imported CLT form the Original Market will not be competitive in NA anymore.

Considering the vast distances on the North American continent, experts also think, that it is most likely, that new manufacturing facilities could be rather small, and regional, especially located in areas of good raw material supply. Taking this thought further, most of global CLT manufacturing, is currently located in central Europe, especially Austria, Switzerland, Germany and Italy. Austria alone manufactures about 500,000m³, which is around 65% of all CLT produced globally (Schickhofer, et al., 2017). The same trend of concentration can currently be seen in North America as well. On the west coast of the North American continent, nearly all CLT expertise can be found in British Columbia (Canada), and in Montana, Oregon and Washington (US). All existing CLT manufacturers in that region can be found within a radius of 600 km around Seattle. On the east coast, there is a second CLT hub in Quebec and Ontario (Canada) and in Illinois (US). The existing manufacturers there fit into an 800km radius around Toronto. This phenomenon is also explained by Schmon et al. (2017), whereas they further conclude, that this trend will continue. They say, looking at rankings of the "greenest" states in the US, shows a correlation with the current development, which leads to the conclusion, that more environmentally oriented states are more likely to play a role in the short- and mid-term development of CLT in the US. Supporting that, Mallo & Espinoza (2014) found, that the success of CLT is highly related to the "green building" movement.

All in all, the future of CLT in North America looks very promising, and experts see an enormous potential. Within the next few years, demand and supply will grow, and the
market will establish a solid structure of operation and support. Possibly even new business models will emerge, to accommodate the specific characteristics of the market. And lastly, CLT might help to modernize the processes how architecture is designed and built in North America, and perhaps even beyond.
VI - CONCLUSION

Considering the short history of CLT, it has already had a major impact on how construction is done in Europe. The Original Market in the German-speaking alpine region of Europe is thriving and there is a global awareness about CLT and mass timber. Therefore, at this point in time, especially lessons that can be learned from the early development of CLT in its initial market can help to foster the growth of new markets such as North America.

There are certain differences between markets that must be considered in order to successfully implement the lessons learned. In the Original Market, people tend to have a more fixed center of life, which makes them very quality-aware and careful. North Americans on the other hand, are more likely to move several times within their lives, so they are more concerned about flexibility and cost. Also, wood as a lightweight building material has a long tradition in North America, whereas massive structures are more common in Europe. The Original Market especially shows a small structured and flexible wood construction industry that is faster in adopting new products.

By talking to experts in both markets, specific opportunities and threats to the development of CLT were identified. Some of them are active on a meta level, such as overpopulation, migration and current environmental issues, which create a need that CLT is able to address. Diversely, other drivers and challenges are related to policies and politics, such as the non-existent CLT standard in Europe and the already used PRG320 and the updated building code (IBC 2015), in North America. Moreover, the continuous governmental support in Canada and the US favors the development of CLT. North America also shows a huge excitement for CLT on many levels and the potential for growth and application in this market is enormous. In contrast, there is a critical lack of professional education in timber construction in North America and the level of expertise around CLT is still very low. In the
Original Market, to the contrary, a broad range of educational services, are available in this field and the related expertise is constantly being advanced. Lastly, the prices of raw timber, are very volatile in both markets and a stable supply can be increasingly challenging.

One of the most important findings, was that companies that also have their own saw mill in addition to CLT manufacturing, tend to have a competitive advantage. Another second strength is a broad portfolio of products. Especially glulam and CLT is a very powerful combination, since they are often used in the same building. By offering all materials that are needed in a project, a manufacturer can be more efficient and therefore more competitive. Lastly, it was found, that, at this stage of CLT development, every CLT company must provide additional services like pre-structural calculations, design assist and technical detailing, in order to sell their products successfully.

The lessons learned that were found in the Original Market, are of very diverse nature. The first one is concerned about education and its importance in fostering a new industry. Especially architects, engineers and developers, need to know and understand CLT. Only if that is fulfilled, the second and third lesson, can be implemented, which are about a holistic building concept and design. It is key to consider all aspects of technical details as well as the design process of a project as a whole. This is key for making CLT buildings efficient. It is also crucial to consider the vulnerabilities of CLT. Wood decays if continuously wet. It is as simple as that, but current up-to-date practices often do not consider that. Research on all water-carrying building services should be more prioritized. Additionally, it was found, that the global tall wood competition is chasing not only records, but also a bit of an illusion. There is only a small percentage of tall buildings that are built in general. Further, the true “sweet spot” for CLT in North America is the mid-rise gap, between 6 and 10 stories. Some other lessons encourage the development of hybrid systems, more care and precision and
not to forget about R&D. Also, some advice on establishing a new CLT production was collected. If the finances are available, a new plant on the green field is more efficient and a better investment for the future. Besides that, it is advised to approach new markets systematically through specific entry point like floors in post-and-beam or light-frame construction, tornado shelters, hotels, and so on. Lastly, two more lessons are concerned about that efficiency is needed for CLT to be competitive now and in the mid-term future.

Summing it all up, there is one theme, that emerges throughout the opportunities, threats, strengths, weaknesses and lessons learned. CLT is all about efficiency. A building made from CLT has to be designed competently, so that architects can choose it above other materials and manufacturers have to produce their products sophisticated and economically. Moreover, a new market as a whole has to efficiently use its efforts to address challenges and threats for CLT, so that it can grow fast and strong.
VII - FUTURE RESEARCH

One of the research findings was that there still is a strong need for more research around CLT and basically every single lesson learned opens up an opportunity for future research. However, there are a few topics that have a special potential for future research:

Any kind of research about developing and advancing BUILDING CONCEPTS and SYSTEMS in CLT are very important right now. In opposition to that, research on the material itself is not very pressing. The only thing that could become important on a material level is finding ways to INCREASE the WEIGHT-STRENGTH-RATIO of CLT. What this means is using less material to make a panel with the same performance.

Also, SOLUTION FOR dealing with WATER DAMAGES and OTHER REPAIRWORK in EXISTING and FUTURE CLT structures is an important issue. This can be about ways to replace panels that are already built into a structure or about new flexible designs that account for eventual repair work in advance. Tall wood buildings are a special case of this.

There is a lot of research done in Europe and by now also in new markets like North America. However, finding existing research can be very hard. An INTERNATIONAL RESEARCH PLATFORM for CLT RESEARCH would be very helpful to make future research efforts more efficient. This could also be done in cooperation with the industry where manufacturers can express research needs and maybe even offer funding.

Another very pressing need is developing OPTIMIZED SOLUTIONS for BUILDING SERVICES in MASS TIMBER BUILDINGS. The special focus should be on all water-carrying members. The optimum would be “No single water pipe enclosed in the floor construction!” Leakage must be visible and accessible right away to prevent wood damage.
The last point would be research on HYBRID SYSTEMS with CLT, with a special focus on the CONNECTION SYSTEMS between different materials. The connection must be efficient and cost-effective for the whole building component to be efficient and affordable. Cost competitiveness is key, there are already many expensive solutions on the market.
BIBLIOGRAPHY


INTERVIEW PROTOCOL:

1 - THESIS OVERVIEW

CLT is becoming global. New countries and regions increasingly realize the potential of what can be done with CLT. As a result, new markets are forming and new companies are entering the industry. Every new region or country that opens its doors to CLT has its own challenges and struggles. However, there is the unique opportunity to learn from the existing original market in Europe and the companies that have been successful there for many years. Especially the greater German-speaking alpine region was, and still is, the cradle of CLT innovation. For that reason, this research, using qualitative methods, analyzes market characteristics and business models of this region. The goal is to find what lessons were learned over the years. In a second step, North America as an example of a new market is analyzed using the same framework. Combined findings give an enhanced understanding of what can be done to foster and fast-track implementation of CLT in new global markets.

2 - CONFIDENTIALITY & RECORDING

- Informing people that the interview is confidential and that all given information is depersonalized before being published.
- Asking for permission to audio record the interview. If not wanted, only field notes are taken.
3 - INTERVIEW QUESTIONS

3.1 - Questions for Experts in Original Market [English]

ICEBREAKER: How did your organization become an expert in CLT?

Q1: In your organization’s opinion, what are the main drivers and opportunities for CLT manufacturers in the greater German-speaking alpine region?

Q2: In your organization’s opinion, what are the main challenges and threats for CLT manufacturers in the greater German-speaking alpine region?

Q3: In your organization’s opinion, what developments and dynamics are to be expected within the North American CLT market in the next years?

Q4: In your organization’s opinion, what lessons can be learned from the original European market to help the North American CLT market to develop fast and efficient?

SNOWBALL SAMPLING:

- What other CLT experts could be helpful to this research?
- What important CLT companies could be helpful to this research?
3.2 - Questions for Experts in Original Market [German]

EISBRECHER: Wie wurde Ihre Firma/Organisation zu einem Experten in Brettsperrholz?

F1: Was sind, in den Augen Ihrer Organisation, die wichtigsten Treiber und Chancen für Brettsperrholzhersteller im deutschsprachigen Alpenraum?

F2: Was sind, in den Augen Ihrer Organisation, die größten Herausforderungen und Risiken für Brettsperrholzhersteller im deutschsprachigen Alpenraum?

F3: Welche Entwicklungen und Dynamiken sind, in den Augen Ihrer Organisation, im Nordamerikanischen BSP Markt in den nächsten Jahren zu erwarten?

F4: Welche Erkenntnisse können, in den Augen Ihrer Organisation, vom Europäischen Ursprungsmarkt gewonnen werden, um dem Nordamerikanischen BSP Markt zu helfen sich schnell und effizient zu entwickeln?

SCHNEEBALLAUSWAHL:
- Welche anderen Brettsperrholzexperten gibt es, die der Studie weiterhelfen könnten?
- Welche wichtigen Firmen gibt es, die der Studie weiterhelfen könnten?
3.3 - Questions for Experts in New North America [English]

ICEBREAKER: How did your organization become an expert in CLT?

Q1: In your organization’s opinion, what are the main drivers and opportunities for CLT manufacturers in North America?

Q2: In your organization’s opinion, what are the main challenges and threats for CLT manufacturers in North America?

Q3: In your organization’s opinion, what developments and dynamics are to be expected within the North American CLT market in the next years?

Q4: In your organization’s opinion, what lessons can be learned from the original European market to help the North American CLT market to develop fast and efficient?

SNOWBALL SAMPLING:
- What other CLT experts could be helpful to this research?
- What important CLT companies could be helpful to this research?
3.4 - Questions for Manufacturers in Both Markets [English]

ICEBREAKER: How did your company get into producing CLT?

Q1: What are the strengths and the USP (unique selling proposition) of your company and how did these aspects develop over time?

Q2: What are the most significant weaknesses and challenges your company had to overcome?

Q3: In your company’s opinion, what developments and dynamics are to be expected within the North American CLT market in the next years?

Q4: In your company’s opinion, what lessons can be learned from the original European market to help the North American CLT market to develop fast and efficient?

SNOWBALL SAMPLING:
- What CLT experts could be helpful to this research?
- What other important CLT companies could be helpful to this research?
3.5 - Questions for Manufacturers in Both Markets [German]

EISBRECHER: Wie ist Ihre Firma dazu gekommen Brettsperrholz herzustellen?

F1: Was sind die Stärken und das Alleinstellungsmerkmal Ihrer Firma und wie haben
sich diese Aspekte über die Jahre entwickelt?

F2: Welche spürbaren Schwächen und Herausforderungen hat Ihre Firma bisher überwinden
können?

F3: Welche Entwicklungen und Dynamiken sind, in den Augen Ihrer Firma, im
Nordamerikanischen BSP Markt in den nächsten Jahren zu erwarten?

F4: Welche Erkenntnisse können, in den Augen Ihrer Firma, vom Europäischen
UrsprungsMarkt gewonnen werden, um dem Nordamerikanischen BSP Markt zu helfen
sich schnell und effizient zu entwickeln?

SCHNEEBALLAUSWAHL:

- Welche Brettsperrholzexperten gibt es, die der Studie weiterhelfen könnten?

- Welche anderen wichtigen Firmen gibt es, die der Studie weiterhelfen könnten?
4.1 - Research Framework

![Research Framework Diagram]

**MARKET**
- Secondary Research
- Personal Interviews
- Political/Legal
- Social
- Demand
- Competition
- Customers
- Existing Structures in Market

**BUSINESS**
- Secondary Research
- Personal Interviews
- Economic
- Technological
- Supply
- Distribution
- Customer Segments
- Value Proposition
- Channels
- Customer Relationships
- Revenue Streams
- Key Resources
- Key Activities
- Key Partnerships
- Cost Structure
- Strategies

**OPPORTUNITIES & THREATS**

**STRENGTHS & WEAKNESSES**

**LESSONS LEARNED**
4.2 - Probing Categories for Expert Interviews [English]

**Political/Legal:** building codes, environmental, regulations, standards, governmental subsidies

**Economic:** GDP, raw material costs, housing starts, square meter prices

**Social:** awareness/perception, environmental awareness, relationship to house, CLT education

**Technological:** IT adaption, construction methods, inventions, R&D, Health, Sustainability

**Demand:** advertising, growth, population, annual newbuilds, user trends

**Supply:** products types, additional services, raw material, value chain

**Competition:** big players, Importers/Exporters, Channel Power

**Distribution:** Sales, communication, marketing & advertising, transportation, value chain

**Customers:** Industrial customers, end-users, general contractors, value chain

**Existing CLT Structures:** residential, public, multi-family, multi-story
4.3 - Probing Categories for Expert Interviews [German]

Politisch/Legal: Gebäude Codes, Regelungen, Standards, Förderungen
Ökonomisch: BIP, Rohstoff Kosten, Anzahl Neubauten, Quadratmeterpreise
Sozial: Kenntnis/Wahrnehmung, Umweltbewusstsein,
        Beziehung zu Haus, BSP Ausbildung
Technologisch: IT Adaption, Bauweisen, Innovationen, Forschung und Entwicklung,
        Gesundheit, Nachhaltigkeit
Nachfrage: Werbung, Wachstum, Einwohner, jährl. Neubauten, Benutzertrends
Angebot: Produktkategorien, zusätzliche Leistungen,
        Rohmaterial, Wertschöpfungskette
Konkurrenz: Große Unternehmen, Import/Export, Channel Power
Vertrieb: Verkauf, Kommunikation, Marketing & Werbung,
        Transport, Wertschöpfungskette
Kunden: Industrielle Kunden, Endnutzer,
        Generalunternehmer, Wertschöpfungskette
Objektbestand: Wohnbau, Öffentlich, Mehrfamilien, Mehrstöckig
Customer Segments: mass-customized, private-industrial customers, import-export
Value Proposition: customer needs, planning, design, prefabrication, R&D, brands
Channels: marketing, sale platforms, awareness, communication, transport
Customer Relationships: personal assistance, co-creation, customer/end-user
Revenue Streams: incoming-outgoing, CLT, additional services, licensing, advertising
Key Resources: physical (Raw material, production line, assembly equipment, trucks)
intellectual/human (formulas, parameters, assembly team),
financial
Key Activities: purchasing, production, customization, prefabrication, transport,
quality control, R&D, site assembly, planning, static calculation
Key Partnerships: suppliers, third party certification, private customers,
general contractors, architects, carpenters, structural engineers
Cost Structure: cost-driven, value-driven, fixed costs, variable costs
Strategies: additional services, vertical/horizontal, . . .
4.5 - Probing Categories for Manufacturer Interviews [German]

Kundensegmente:  Masse-Individuell, Privat-Industrie Kunden, Import-Export
Leistungsangebot: Kundenbedürfnisse, Planung, Design, Vorfertigung, R&D, Marken
Vertriebskanäle: Marketing, Verkauf, Kenntnis, Kommunikation, Transport
Kundenbeziehungen: Persönliche Betreuung, gemeinsame Planung, Kunde/Endnutzer
Einnahmequellen: Eingehend-Ausgehen, BSP, Zusatzleistungen, Zulassung, Werbung
Wesentliche Ressourcen: Physisch (Rohmaterial, Fertigungslinie, Montage Ausrüstung, LKW)
                        Intellektuell/Menschen (Formeln, Parameter, Montageteam),
                        Finanziell
Wesentliche Tätigkeiten: Einkauf, Fertigung, Personalisierung, Vorfertigung, Transport,
                        Qualitätskontrolle, R&D, Montage, Planung, Statische Berechnungen
Wesentliche Partner: Lieferanten, Zertifizierung durch Dritte, Privatkunden,
                    Generalunternehmer, Architekten, Zimmerer, Bauingenieure
Kostenstruktur: Kostenfokus, Wertfokus, Fixkosten, Variable Kosten
Strategien: Zusatzleistungen, Vertikal/Horizontal