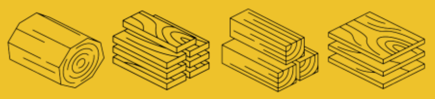
# REFLECTION

## ASSESMENT OF THE RESULT AND THE FUTURE APPLICATIONS



# DISCUSSION

## THE RESEARCH STRUCTURE AND THE RESULTS:

**The Big picture:**

### DOCUMENT STRUCTURE

This research embarks on an exploration of the potential integration of climatic conditions, particularly humidity variations, in the context of developing an alternative prefabricated wood housing system tailored to the unique geographical, climatological, and socio-economic conditions prevailing in Colombia. The research unfolds through several key phases, each of which contributes to a holistic understanding of this multi-layered work.

The ultimate goal of this study is to create an affordable and sustainable solution addressing the social housing crisis in Colombia. It aims to develop a wood-to-wood connection system that harnesses the material's properties, digital manufacturing technology, and structural performance. This system is designed to simplify the construction process, especially for inexperienced users, by leveraging the material's ability to swell in response to environmental humidity.

To assess the viability and impact of this innovative approach, the research was divided into four distinct branches. Each of these phases allowed for an in-depth exploration of the system, starting from specific aspects such as the material properties and progressing to the practical implementation of a housing unit within the Colombian context. The ultimate objective is to revolutionize the construction industry and positively influence the social conditions of vulnerable populations in Colombia.

This research project followed a structured approach that consisted of four main phases:

**Wood Industry Assessment:** This phase involved a rapid evaluation of the wood industry in Colombia to identify the types of wood products available for use in the study.

**Material Science and Properties:** The second phase focused on understanding the properties of wood, particularly how it responds to changes in humidity. This knowledge was essential for integrating the material's behavior into the construction process.

**CNC Manufacturing Assessment:** The third phase revolved around evaluating the potential of CNC (Computer Numerical Control) manufacturing technology, considering the materials available in the Colombian context. This phase also explored the most effective wood joint connections for manufacturing.

**Structural Assessment:** In the final phase, the study examined various wood joints and structural elements like beams and columns. This analysis aimed to determine the optimal sizes, weight, and construction implications in relation to the material properties.

The findings from each of these four branches were integrated to propose a comprehensive building system. This system, driven by the ability of wood to interlock itself in response to humidity, eliminates the need for screws and glue, making construction more sustainable and efficient.

### RESEARCH PROCESS DEVELOPMENT - CLIMATE

A clear understanding of climate and regions in need of this technical solution established the principal boundary conditions of CNC manufacture, and material evaluation to the building assembly constrains:

**Boundary conditions:**

3. Average relative Humidity of populations in need 80%-85%, as great part of the country.
4. Average relative humidity of CNC machinery locations: 60% - 65%
5. Temperature ranges 23 to 27 degrees Celsius, as 86% is restrained to these conditions.

These boundary conditions were used to study the hygroscopic properties of wood, the primary intension was to identify the ideal specimen for the experimental construction process.

### METHODOLOGY – MATERIAL SELECTION

Due to a wide range of material sub species, as well as limited access to tropical specimens. The study commences by selected the most common and similar samples, intending to homologate material behavior in the Colombian Context. Thus, Douglas Pine, Larch, Ash, Oak Quercus Robur, Meranti, and

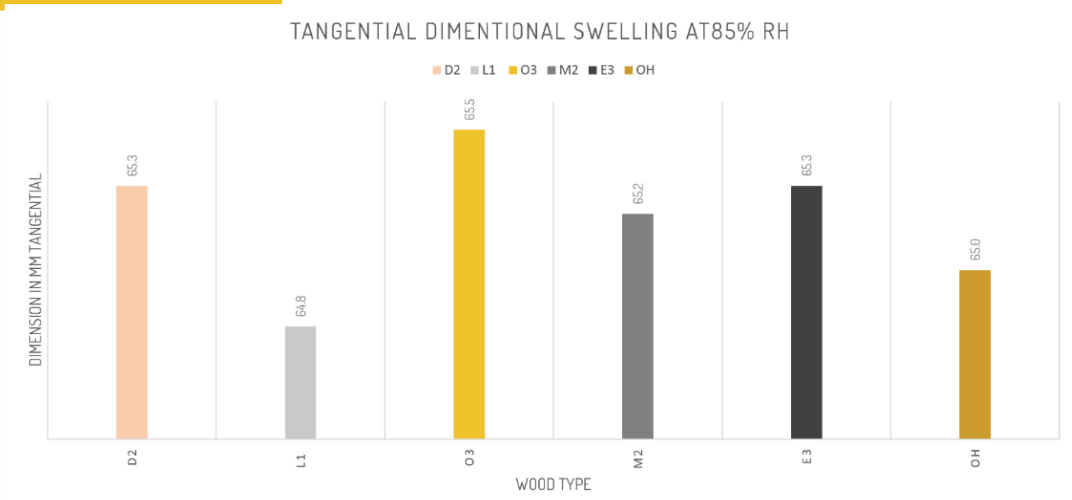



*Figure 106 Final dimensional change in tangential fiber direction after 30 days*

Elm were under close evaluation to find the most appropriate material to implement principles of volumetric change due to changes in Relative humidity.

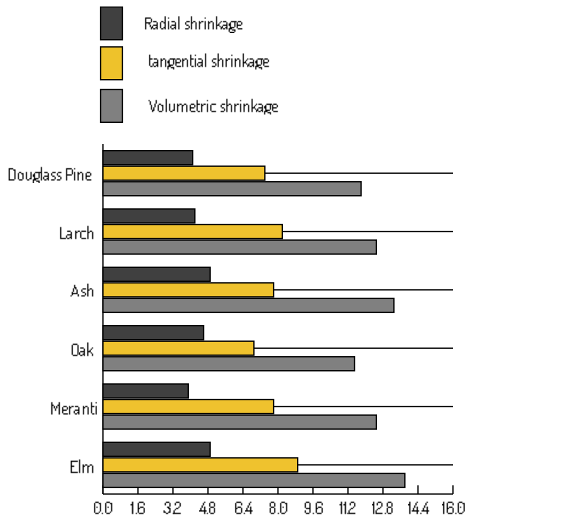



*Figure 107. Tangential, radial and longitudinal Shrinkage of several wood spicies*

## METHODOLOGY – MATERIAL EXPERIMENTATION.

*Figure 108 Wood samples for experimentation*

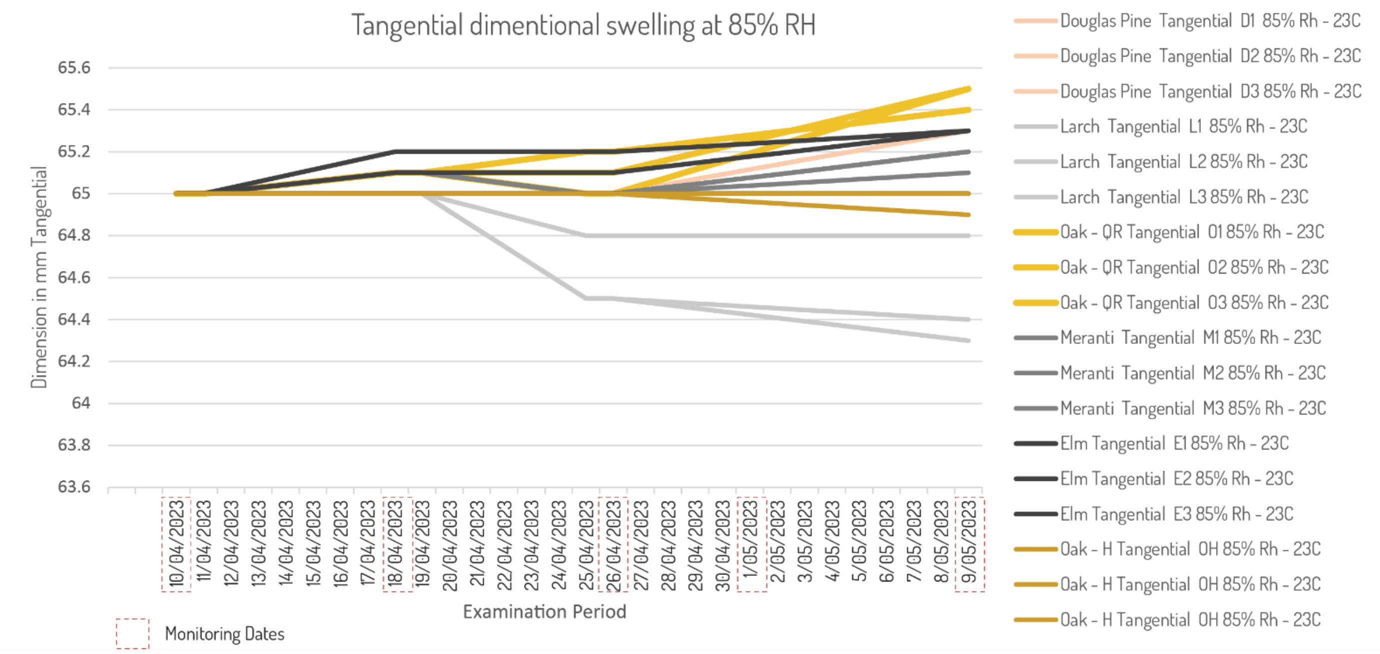
Based on this selection, batches of material samples with similar conditions were under constant monitoring, several material iterations were created to compare and demonstrate results. After a thrilling experimentation phase the Oak Hardwood Quercus Robur shows a consistent and outstanding performance to explore the integration of swelling effects into wood-to-wood connection with interlocking capabilities due to moisture change.

## RESULTS

The results observed in figure 108 demonstrate three fundamental research outcomes.

**Material Performance**

This experiment finds Oak Quercus Robur hardwood as the most suitable specimen for exploration into the applications of Moisture change in interlocking process of wood-to-wood Connections. Nevertheless, other potential species




such as Douglas Pine and Larch wood types show swelling capabilities into the wood-to-wood interlocking systems. Further research into these alternatives is necessary as this type of material offers a more affordable solution.

**Time Frame**

Some literature research mentioned the time required for the material to reach (FSP) Fiber saturation point up to 60 days, in other words, maximum fiber direction change. Nevertheless, this rigorous study is possible to demonstrate that after a 30 day process, wood specimens reach maximum physical change performance. This data is taken into consideration to formulate a manufacturing and assembly process to create optimal construction workflows.

**Joinery Tolerances**

wood dimensional changes from initial state to fully dimensional change was identified. After constant 30-day humidity exposure the wood samples of Quercus Robur reach an additional + 1.5 mm material swelling. This process was conducted from a material Moisture content of 9.30% up to 15% MC.

**Methodology evaluation,**

The scientific experimentation based on literature research gave the ideal framework to demonstrate material capabilities. Following the study of (Karagüler & Kaya, 2017) a research methodology was stablish an set in practice to evaluate material conditions. Due to the effectiveness of the process, which created a close experimental environment was possible to isolate the climate conditions desired for evaluation. Therefore, this rigorous reduces results errors, and creates an effective process.

*Figure 109 taken from the research paper of (Karagüler & Kaya, 2017) effects of relative humidity and moisture in durability of spraude and laminated timber.*

**Material Methodology success**

Due to the success of the first stage of experimentation, this methodology was repeated in further stages, such as the implications of the material into the wood-to-wood joints as a mean to demonstrate the structural capabilities of the proposed building system.

This consistent evaluation strongly demonstrates the effectiveness of this specific theory. Moreover, aiming to answer the main question as follows:

**Main Research Question:**

To what extent can 3-axis CNC milling, a digital manufacturing technology, be utilized to fabricate wood-to-wood connections in sawn timber structures for low-cost housing in Colombia while adhering to Design for Manufacture and Assembly (DfMA) principles?

This methodology allowed for the study through each development stage to include more variables. For instance, the first experimentation which can be seen in the material exploration chapter starts from using small 65x65x65 mm samples. By the end of this research, it was possible to compare complex manufacture wood joints, keeping the same experimental conditions.

## EXTEND OF THE STUDY: DRASTIC RELATIVE HUMIDITY ENVIRONMENT CHANGE

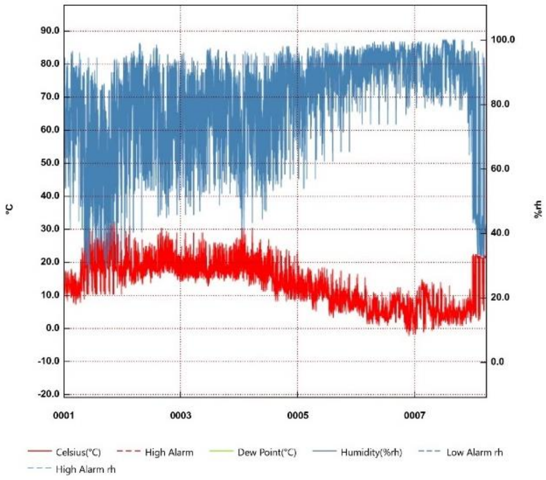
During the stabilization process, wood tends to warp, and bend following the fiber direction in the process s of moisture release or absorption. Due to the size of the specimens as well as impossibilities to test the structural samples under constant load is not possible to demonstrate the repercussion of this mechanism of assembly in long term effect. Thus, a branch of this research can be originated from this absence.  Despite aiming to propose a fully functional building system, a rather complex task means demonstrating each and one of the specific topics that can be generated in the development of the research.

**Time frame and planning**

As observed, the experimentation timetable required a long prosses of monitoring to produce reliable data.  Additional laboratory equipment was implemented to keep records of such a detailed study. For instance, equipment such as the moisture sensor proves efficient to maintain and demonstrate ideal experimental values. The fluctuations in the graph can be seen  due to the monitoring of the specimen ever week, which had to be taken out of the close environment, momentarily reduction climatological conditions.

**Mathematical research**

A valuable approach of the material was the understanding of the mathematical theory behind the volumetric change:




An outcome of this study can be referred to the understanding of the close relation between material Density, and fiber volumetric change, which is confirm by an extend literature research, point at the tangential fiber direction as the characteristic that shows bigger changes.

The numerical values were constant, nevertheless there are some discrepancies in data source regarding physical properties of the wood, such as shrinkage ratios, which differ from source to source.

$$FSP = S_v \cdot G_{H_2O} / G_0$$

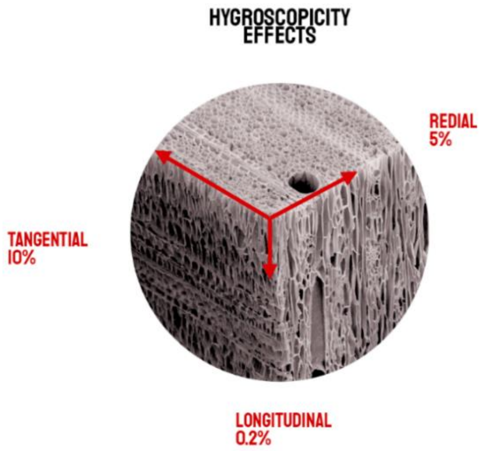
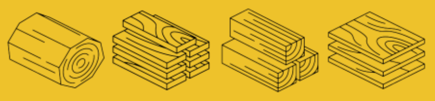



*Figure 110 Fiber direction shrinkage ratio taken from PhD candidate Max Salzberger.*



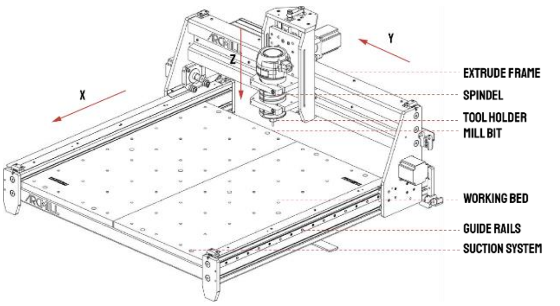
# CNC ASSESSMENT

## CONSIDERATIONS FOR DESIGN

### THE BIG PICTURE

The primary objective of the manufacturing study is to gain a comprehensive understanding of the capabilities and limitations of CNC (Computer Numerical Control) technology in fabricating traditional joinery connections using sawn timber. This study explores the feasibility of employing non-conventional wood products, specifically sawn timber, in a manufacturing setup, with the aim of assessing its potential applicability in the Colombian context where CNC technology is readily available.

The research encompasses a thorough investigation of various aspects, including working areas, anchorage points, material positioning, precision, production time, material hardness, and other critical factors. These evaluations are pivotal in determining the efficiency and effectiveness of the CNC manufacturing process in the context of different wood-to-wood connections, with broader applications in the research and construction domains.




In light of the insights gained during the prototyping stage, a set of constraints has been established. These constraints serve as general guidelines for the production of traditional wood joinery connections using a CNC machine and sawn timber elements. They encompass the following key considerations:

**Cross section**

The following machine conditions provide clear limitations and requirements of the design. As can be seen, the cross sections of the elements cannot reach 100 mm in the Z-Axis. Disregarded structural requirements, the design needs to be adjusted to this limit.

**Length**

As mentioned in the CNC evaluation sections, a limit length of 3000 mm is taken as most of the machinery presents an average maximum length around this dimension.

9. Z-Axis Working height limit 100 mm
10. Y-Axis Dimensional limit 1200 mm
11. X-Axis dimensional limit 3000 mm

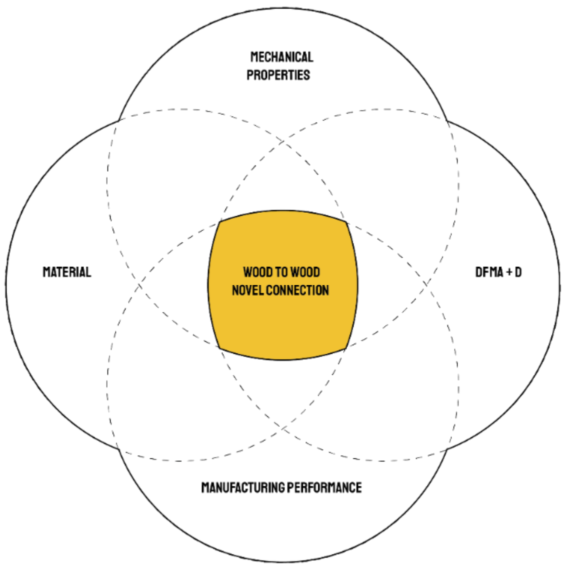
### TOOLING LIMITATION

The tooling limitation drastically altered the decision making towards choosing the wood-to-wood joint. As follows you can see a detailed characteristic condition of the milling performance studied at TU Delft University.

12. Maximum Mill bit Diameter 10 mm
13. Maximum Mill bit high 60 mm
14. Free movement limit after material 5 mm
15. Feed rate conditions: 600 mm/min
16. Step Down layer conditions: 2.0 mm

## THE GOAL - FOUR FUNCTIONS

As elaborated in the CNC study, the manufacturing perspective of this research project was guided by four primary objectives. Firstly, the selection of the material was based on the outcomes of the experimental stage, leading to the choice of Oak Hardwood as the preferred material. Secondly, careful consideration was given to the fiber direction of the elements. This was essential to design components that could maximize the tight-fitting effects, particularly in response to variations in relative humidity over time.



The third objective centered on achieving optimal structural performance in the joinery connections by focusing on the mechanical properties. Lastly, each joint design was meticulously crafted in accordance with the principles of DFMA (Design for Manufacture, Assembly, and Disassembly). These elements were integral in shaping the final decisions made within the research project.

## LIMITATIONS

Due to machinery restrictions at TU Delft University regarding material hardness, it was not possible to produce a continuous research process. This set back opened the opportunity to conduct a deeper analysis in Koln, Germany, were thanks to the support of my third mentor Max Salzberger, a fully experimental study was developed to demonstrate manufacturing performance.

## RESULTS

## JOINERY ASSESSMENT

**Mortise and Tenon**

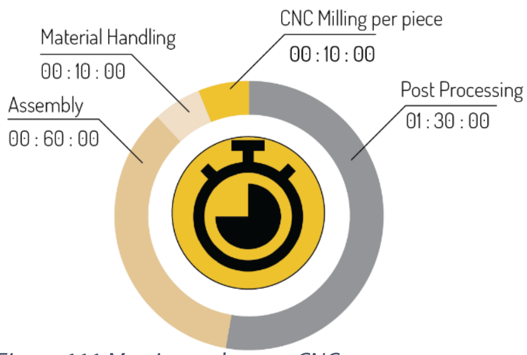



*Figure 111 Mortise and tenon CNC assessment*

**T- Joint**

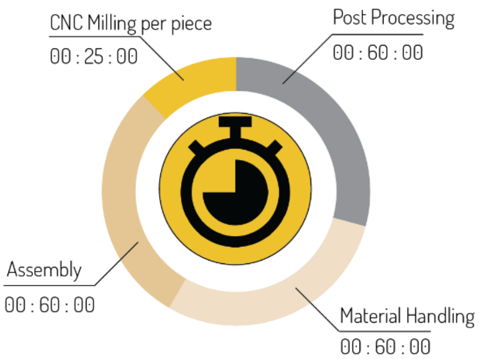
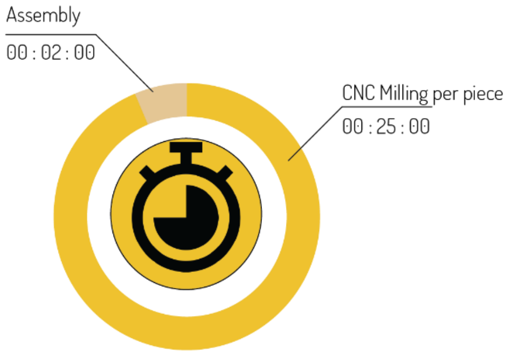



*Figure 112 T-Joint CNC Assessment*

**Cross-Half lap**

*Figure 113 Cross-Halft Lap CNC Assessment*




## CONCLUSION OF CNC JOINTS

### CNC MILLING

First and foremost, it is important to note that manufacturing traditional joinery connections like mortise and tenon or T-joints using this type of technology isn't well-suited. The manufacturing process is designed around a 2D strategy for panel production, and attempting to create complex geometry requires additional manual labor, which can quickly diminish the quality and production efficiency of wood elements. This often leads to the necessity of post-production steps to correct any misalignments, essentially reverting to more traditional carpentry craftsmanship.

## THE SELECTED JOINT

Contrary to the negative repercussion on the previous two joint examples, the Cross-Half lap joint presents an outstanding performance in manufacturing as well as assembly. From the CNC milling time overview, despite showing a higher production time, this detail achieved excellent precision resulting in time savings of about 150 minutes compared to the Mortise and Tenon, and T-joint connections.

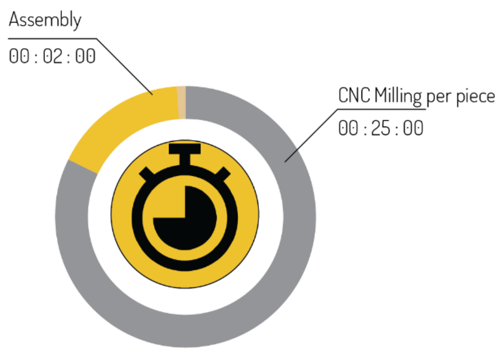
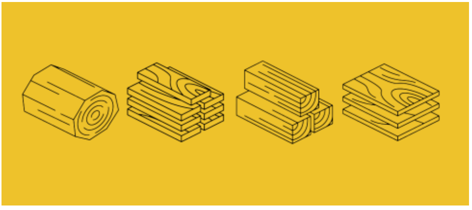



Figure 114 time saving Cross-Half Lap



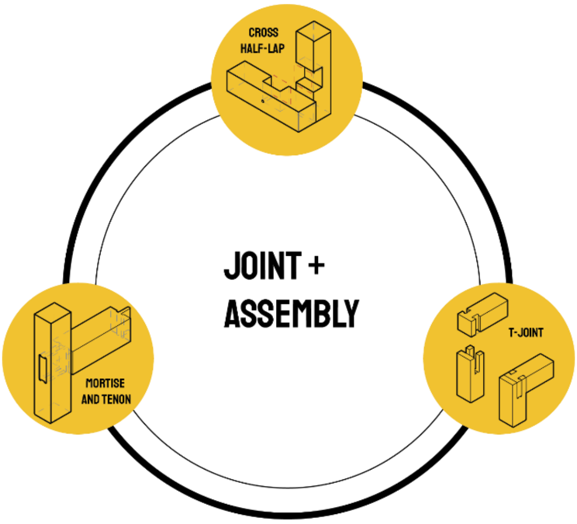
## SUB-QUESTION:

How can the advantages of assembly efficiency achieved through digital manufacturing be extended to materials of lower precision, such as locally sawn timber available in the Colombian forestry industry?

There is not a simple answer for this question but a rather complex set of considerations and findings that were identify in the potential of this technology:

### MATERIAL:

Sawn timber is by nature an irregular element in the building industry. Contrary to EWP's plates, beams derive directly from the trunk presents nonhomogeneous characteristics, such as fiber direction of the grain, number of nodes present in the pieces, grain orientation, cross-section related to the drying process, among other characteristics that will influence the movement of wood in the drying process. These natural changes of the material have to be tackled in the pre-manufacturing process by aligning the face of the beams into a perfect 90-degree angle. Understanding that the used of any sawn timber element requited additional reprocess to increase the precision of the machine. As you maybe see in the CNC chapter, the prototypes produced without this preparation clearly show a negative impact in the joinery connections.




### WORKING AREA

The CNC machine's working areas are notably constrained, especially when compared to conventional Engineered Wood Products (EWP) dimensions, which typically measure 1220 x 2400

x 18 mm. This significant disparity between the CNC machine's capabilities and the industry standards creates challenges in transitioning from design to the actual implementation of timber elements using this equipment.

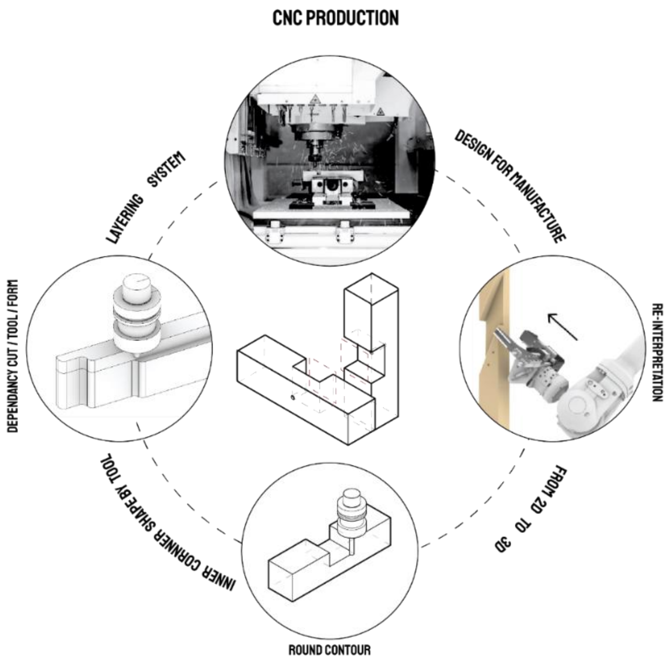
Furthermore, there is a clear limitation in terms of cross-sectional dimensions, particularly with a maximum limit of 100 mm. This constraint poses a significant challenge if solid wood is intended to be used for constructing larger spans. As a result, the application of this technology is best suited for lower rise building scales, and its effectiveness diminishes when dealing with larger and more substantial structural elements.

## CONSIDERATIONS FOR FUTURE RESEARCH

After a meticulous assessment of CNC possibilities and the development of strategies aimed at achieving a more sustainable manufacturing process from an efficiency perspective, it becomes evident that this equipment is not ideally suited for this type of building system. The mechanics of the apparatus are rather constraining and challenging to control, resulting in numerous problems affecting the quality of the produced joints. Most of the equipment used in this research was primarily focused on academic production, and as such, the manufacture format appears inefficient and entirely unrelated to the cross-sections and dimensions of the sawn timber. A more conventional production process aligned with this building system would likely lead to decreased production times and improved efficiency.

Nevertheless, the cross-Half lap joint is rather flexible in the manufacturing constraints. This decision benefit further implementations of the system into a high-end process, where topics of manufacture for high productivity, and supply chain could be integrated into the study.

Moreover, their results observed in the assembly, and manufacturing assessment reveal the potential that this simple joints could play into modern constructions.




## WHAT'S MISSING?

### MODEL TO PRODUCTION DIGITAL WORKFLOW

The parametric model is an essential component for assessing the joint capacity within the context of the entire skeleton structure. In the initial stages, a Grasshopper script was created to facilitate structural analysis. While this tool is partially resolved, there is room for improvement by developing a script for more automated and efficient analysis.

With a fully automated system in place, the model can quickly assess the structural capabilities in relation to the joint capacity. This level of automation allows for easier adjustments in the fabrication process and streamlines the overall workflow. It enhances the model's ability to adapt to changes and optimizes the fabrication process based on structural requirements.

### ROBOTICS IN THE RESEARCH

This branch of research draws partial inspiration from the Gramazio Kohler Institute, which has explored wood-to-wood connections in digital manufacturing with a focus on assembly mechanics using robotic systems. However, this master's thesis research takes a distinct approach by examining the application of high-tech solutions in a Latin American context. This context is characterized by specific limitations in technology, available materials, and assembly processes, which have influenced the decision-making process in manufacturing and joinery.

While robotics is not a primary focus of this research, the core topic centers on understanding how wood, when combined with the precision offered by digital manufacturing tools, can be leveraged to create a more user-friendly assembly process. This approach aims to enhance assembly efficiency, reduce reliance on other materials that are less environmentally friendly and challenging to recycle, and ultimately develop a solution that is accessible to individuals who seek to construct their own homes.

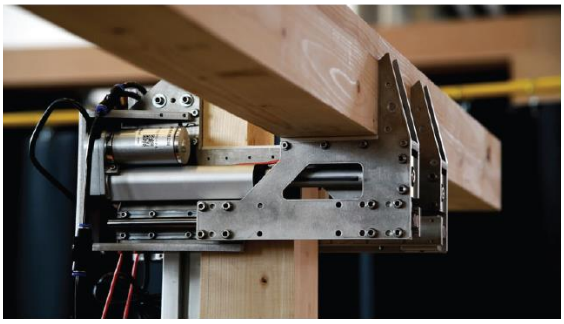


*Figure 115 Gramazio kohler institu - Timber assembly with distributed architectural robotics 2018 – 2022*

## MECHANICAL PERFORMANCE VS MOISTURE INDUCE EFFECTIVENESS

### CONCLUSIONS

From the mathematical and numerical analysis, it can be concluded that the Cross-Half Lap connection shows superior structural ultimate bending moment performance with (2.45 kN/m). In contrast, the Mortise and Tenon joint presents almost half of the structural performance with (1.74 kN/m). Lastly, the T-joint connection appears to be the least optimal for housing structural applications (1.54 kN/m). Thus, according to the data, the Cross-Half Lap Joint presents itself as the most structurally optimal choice.

Based on the previous numerical analysis, the T-joint will be excluded from further research consideration as its overall CNC manufacturing performance, assembly, and structural capacity seem inefficient for any application.

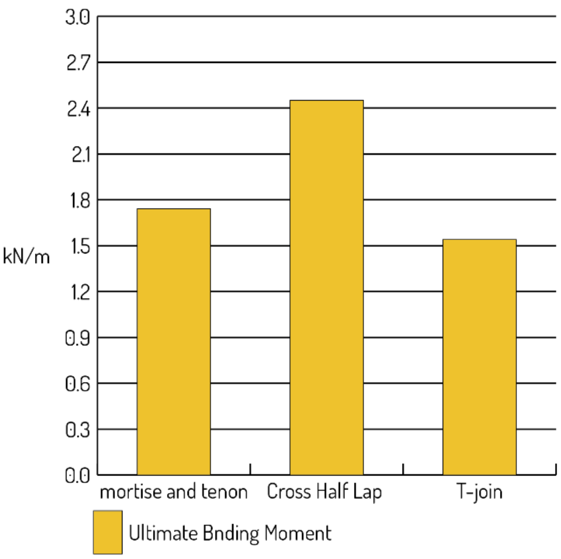



*Figure 116 Ultimate Bending Moment Capacity*

### METHODOLOGY

The structural analysis of wood-to-wood connections, despite involving the same quantity of wood, the same cross-sectional dimensions, and the same wood types, reveals a notably superior performance of the Cross-Half Lap joint. The process of mathematical analysis and assessment was complex, primarily due to the limited existing research on wood-to-wood connections in the academic field.

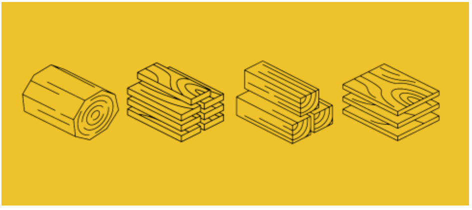
To address this limitation, this research employed a three-stage approach to verify and establish the structural performance of the connections. Firstly, a mathematical characterization of the wood joints was developed based on a comprehensive literature review. Various calculation methods were tested and proven to be effective in comparing different joint types, marking the initial phase of the analysis. Following this, a numerical analysis was conducted using Ansys Workbench, which served to validate the data obtained from the mathematical calculations.

However, the most tangible evidence of this research's findings came from the practical mechanical testing of real wood-to-wood prototypes subjected to compression and tension stress. This final stage of experimentation not only confirmed the results obtained from the previous calculations but also provided a clear understanding of the relationship between joint geometry and structural performance.

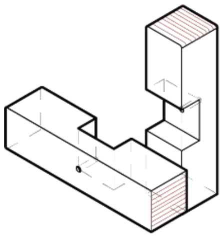
*Figure 117 Compression test Laboratory of Mechanics-3ME faculty TU Delft University*

### PROVING THE EFFECTIVENESS OF MOISTURE INDUCE JOINTS TO TENSILE STRESS

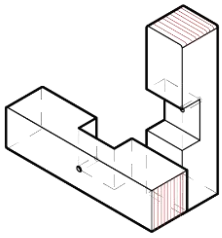
The experimental testing conducted on the Cross-Half Lap joint, as described in the structural characterization section, has effectively demonstrated the significant impact of relative humidity (RH) on wood-to-wood connections. This revelation opens up exciting possibilities for its application in the construction industry. Through a meticulously designed experimental methodology, several critical points can be argued:



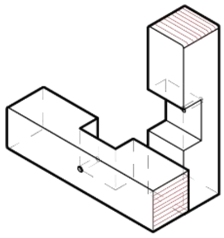
RED -3-4-65%



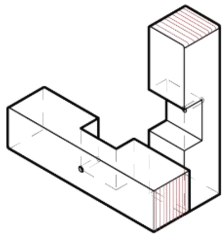
RED -5-6-65%



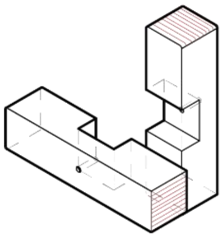
RED -1-2-85%



RED -7-8-85%



BLUE -3-4-65%



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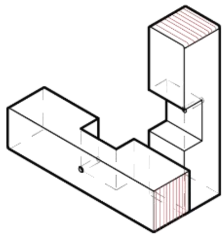


**CNC MANUFACTURING PRECISION:** The study underscores the importance of CNC manufacturing methods in elevating production quality and precision, especially in wood-to-wood connections. It clearly establishes the superiority of CNC manufacturing when compared to less precise specimens. This precision is vital for achieving strong and reliable connections.

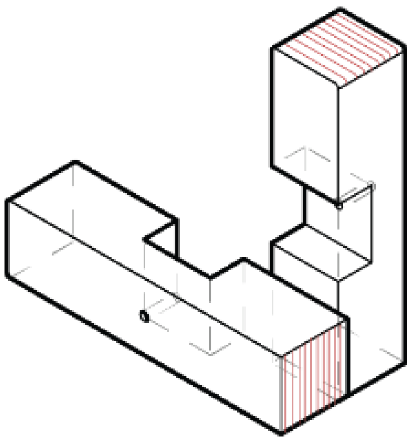
**TANGENTIAL GRAIN DIRECTION:** The assembly method using the Cross-Half Lap joint showcases an exceptional structural performance, particularly when the tangential grain direction is maintained. This approach ensures optimal interlocking between elements, resulting in superior structural integrity. The graph provided illustrates this advantage.

**EFFECTIVENESS OF MOISTURE INDUCTION:** The experiment involving different RH levels reveals the remarkable effectiveness of moisture induction in enhancing the joint's performance. The specimen labeled "RED-7-8-85%" demonstrates an outstanding tensile force of 3000 N, thanks to the environmental RH acting as a slow interlocking mechanism. In stark contrast, the specimen "RED-5-6-65%" with identical characteristics but without moisture induction exhibits a significantly lower tensile resistance of about 1600 N. Both specimens share the same material configurations, machining processes, and milling, highlighting the pivotal role of RH in enhancing the joint's properties.

This research not only sheds light on the critical role of CNC manufacturing and grain direction but also underscores the potential benefits of leveraging environmental factors, such as relative humidity, to optimize wood-to-wood connections. These findings hold promise for advancing construction techniques and materials, offering more robust and reliable solutions for the industry.

The tangential grain direction assembly method archived with the Cross – Half Lap joint reveals a superior structural performance using this particularity as part of the design integration.

**RED -7-8-85%**



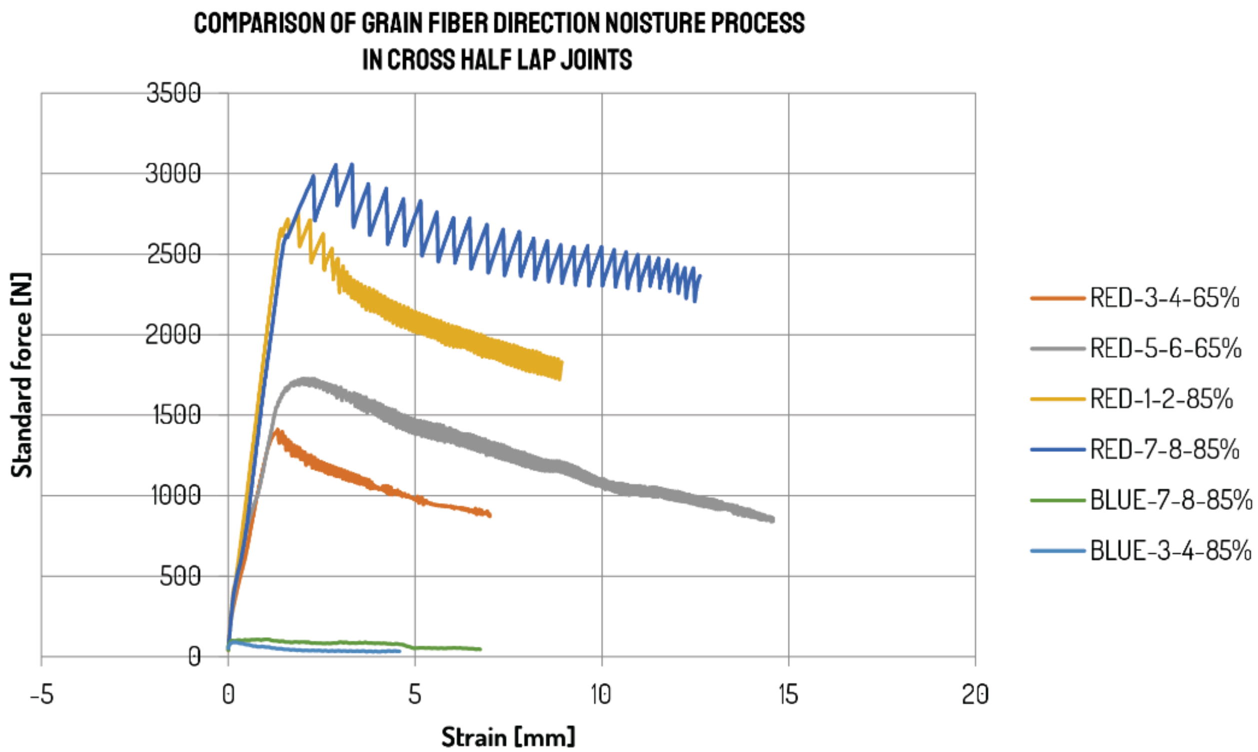



*Figure 118 Tensile Test Result of moisture induce Cross Half Lap joints*

## LOOKING AHEAD

**Effectivity in Real Scenarios:**

Evaluating the effectiveness of the system in real-world scenarios is crucial. Consider factors like ease of transportation, adaptability to different locations, and how it compares to other construction methods. If lab results indicate limitations in applying the same system in certain conditions, it's essential to outline those limitations clearly. This research has proven the benefits of Relative humidity integration as part of the design of structural elements to maximize assembly process in a short-term scope. Further research into long term effect of these joints is fundamental to evaluate the effectiveness of the structure.

**Financial Aspects:**

Assessing the financial feasibility of the system is fundamental for this project. As seen in the design analysis of price per component, Oak is considerably more expensive than other rather more affordable materials.

It is important to determine whether this building system is suitable for social housing applications or if it's more appropriate for higher-income populations. The cost of the overall structure represents a large investment, as Oak is one of the most expensive wood products in the construction market.

**System Downsides:**

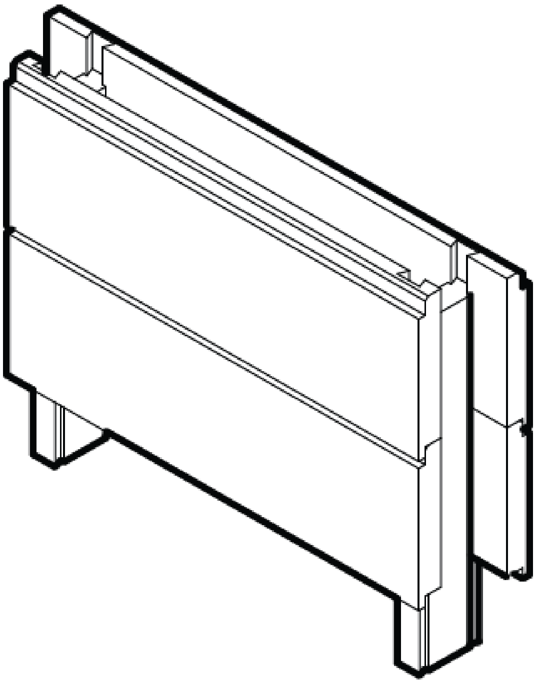
The drawbacks of the system at various stages, from wood processing to CNC milling and assembly showed optimal material waste, production time, and simplicity of assembly. One methodology that is rather not examined is the assembly of elements on site. As the effectiveness of this building process work with a tight-fitting assembly method that requited high pressure of installation. A big question is what speed performance would be counting with the proper tool.

**Time Gap Between Milling and Assembly**:

Is an interesting aspect of the research. As proved in the Material experimentation, there is a 30 window until the elements are fully saturated. Nevertheless, a negative possible outcome is the transportation of parts, and not immediate assembly on site. The tolerance of the system will dramatically affect the building process in later stages.

**Positive Aspects – sustainability outcome:**

A significant contribution to both science and society is the positive sustainability impact of this research, as demonstrated throughout the study. This research has successfully developed a structural system that eliminates the need for glue or steel hardware. By utilizing material pressure in combination with traditional joinery methods, it proposes a manufacturing and assembly approach that removes the dependency on glue and screws. This not only simplifies remanufacturing and repurposing processes but also offers the advantage of adaptability. The wood elements can be used in various configurations, including smaller building components, making them easier to transport, handle, and reprocess in later stages.



## IMPROVEMENTS AND REPLACEMENTS:

Although the research has provided valuable insights, it's important to acknowledge that due to prototyping limitations, the entire building sequence has not been fully tested. While each independent joint was studied, engineered, and assembled successfully, further development of the entire system is essential to fully comprehend the effectiveness of the proposed construction method Suggest areas where the system can be improved or where alternative materials or processes might be considered. This demonstrates a forward-thinking approach to system enhancement.

**Disassembly process – UN-successful outcome.**

A significant challenge highlighted by this study is the difficulty of disassembly within the proposed system. The tight-fitting process, optimized through material swelling, presents obstacles to effective disassembly. As demonstrated in the CNC chapter, a substantial amount of pressure is required to position the joints, making disassembly a complex task. This issue raises critical questions for the research:

**User-Friendly Disassembly:** Exploring methods to make disassembly more user-friendly should be a priority. Designing a system that allows components to be easily detached without the need for excessive force or tools is essential.

**Environmental Impact:** One approach could involve transporting the structure to an environment with lower relative humidity (RH). In such conditions, the natural reduction in material swelling could lead to automatic disassembly of components. However, the logistics of moving entire structures pose significant challenges.

**Permanent Structures:** Alternatively, it's worth reconsidering the implications of disassembly in the context of more permanent structures. In situations where the intended use of the building is long-term, disassembly may be a less critical factor. The focus could shift toward optimizing the assembly process for stability and longevity.

**Material Selection:** Evaluating the impact of different wood types on material swelling and disassembly could be a valuable avenue. Some woods may exhibit less swelling, making disassembly easier, while still providing the desired structural properties.

**Mechanical Solutions:** Investigating mechanical solutions to facilitate disassembly, such as innovative joint designs or mechanisms that release pressure when needed, should be explored.

**Community Involvement:** Engaging with local communities and potential users can provide insights into their specific needs and preferences regarding disassembly and reassembly. This feedback can guide the development of user-friendly solutions.

Addressing the challenges of disassembly is crucial, as it not only impacts the practicality of the system but also influences the sustainability and adaptability of the structures. By considering these options, the research can work towards a more well-rounded and comprehensive solution for building construction and deconstruction.

**Scientific Contribution:**

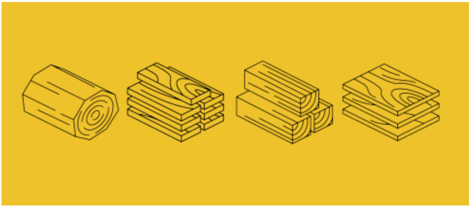
During the Literature Research it was possible to notice the scarcity of this specific research topic. Some similar findings revel the applications of compress hardwood dowels with moisture difference. (Mehra et al., 2021) This research finding reveals the configuration of structural elements base on their on-material moisture behavior and the interaction with the environment.

## THE RELEVANCE IN SOCIETY AND TECHNOLOGY – BT MASTER TRACK

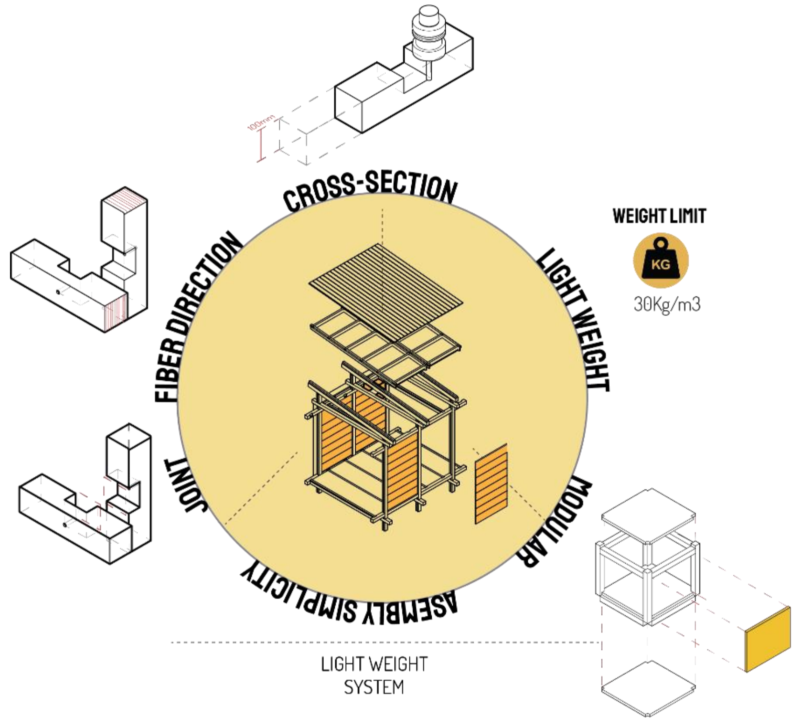
### BUILDING TECHNOLOGY MASTER TRACK

The primary motivation for pursuing the master's track in Building Technology is rooted in a deep desire to contribute to the advancement and improvement of the social conditions in my home country, Colombia. The principal goal of this research is to serve as an inspiration for future technical advancements that can play a crucial role in rebuilding societies affected by conflicts. For instance, the research aspires to offer an innovative and rapid construction system that could be invaluable in addressing a conflict that has persisted for the past half-century.

This comprehensive research journey encompasses a wide range of subjects, including material science, digital manufacturing, and the structural assessment of wood-based constructions. However, the ultimate vision for this research and development effort extends beyond these individual components. It seeks to create a technical solution that is accessible to everyone, providing opportunities for dignified housing and significantly improving the lives of those it serves.



## THE INFLUENCE OF THE RESEARCH IN THE DESIGN / DESIGN IN THE RESEARCH




This research project follows a well-defined path, with a strong emphasis on three key aspects that significantly impact the final system. Importantly, each of these aspects informs the subsequent stage of the research, creating a coherent and interconnected framework. As a result, the progressive studies of the material, CNC manufacturing, and, ultimately, the wood joint continuously shape various elements of the system, including its size, weight, structural performance, and more. One of the most significant outcomes of this research project is the profound understanding of how the expansion of the material harmoniously interacts with the geometry of the joints. Furthermore, it delves into how these joints are produced through CNC technology and, ultimately, how all these elements cohesively form a congruent system that functions in collaboration at every stage of the process.

The research approach employed here serves as an effective model for demonstrating the advantages and drawbacks of each design decision. While this approach involved an extensive study of various topics, it simplified the decision-making process. It made it easier to visualize the options available, as the most favorable and least favorable choices were clearly identified. Moreover, it emphasized how each aspect could inform and influence the final design.

# RESEARCH STRUCTURE