

# **The Missing Step**

Applying Lean Principles to an Existing Product

## Abstract

Author(s)	Publication type	Completion year
Luis Antonio Valderrama Sonoda	Thesis, UAS	2025
	Number of pages	
	39	
Title of the thesis		
<b>The Missing Step</b> Applying Lean Principles to an Existing Product		
Degree, Field of Study		
Bachelor of Culture and Arts, Industrial Design		
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<p>The main objective of this thesis was to redesign an existing wooden pendant lamp by applying the principles of lean design. The aim was to improve production efficiency, reduce costs, and minimize waste.</p> <p>Nowadays, there are many handmade lamps in the market, and these artisanal designs are usually expensive to produce and generate a large amount of waste of resources.</p> <p>The work was carried out using a qualitative methodology, based on bibliographic research, compilation of information from digital sources, critical analysis, and interviews with design experts.</p> <p>This thesis is the result of a process of analysis, redesign, and prototyping. The project is mainly aimed at designers and small companies that seek to manufacture products in a more efficient, sustainable way and adapt to current market needs.</p>		
Keywords		
Industrial Design, Manufacturing, Product Development, Cost Efficiency, Resource Optimization, Innovation, Competitive Advantage, Lean.		

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## 1 Introduction

### Project Background

The story begins while studying carpentry at the Salpaus school in Lahti. Daily observations revealed that the wooden waste container filled rapidly, the students mostly used a part of the wood and threw away the leftovers, but those leftovers often used to be new and very high-quality parts, often with materials that had hardly been used or modified. Some of these materials were large pieces of wood that could still have been utilized for the production of components of a piece of furniture or new designs.



Image 1. Example of rubbish can at the LAB University of Applied Sciences

The inspiration for creating a product that could have a low cost and high value started with these questions: What can be made using those extra parts? How to increase the value? Which shape can be accepted by people? And above all, which product shape would take the least time to manufacture?

After selecting wood pieces of similar shape, each approximately 70 to 80 centimeters in length, the next step involves accurately cutting them using a bandsaw machine, obtaining sheets approximately one and a half millimeters thick. As it was being cut, the strips fell to the floor, and it was noticed how light and fragile they were. The development of a product that required minimal physical contact led to the selection of a pendant lamp form as a suitable solution.

After finishing cutting them, the pieces of wood were straight. To create a simple lamp shape, they were bent, but not too much, or they would break. In the end, it managed to maintain a certain curvature. Another machine was used to cut smaller pieces that would serve as both the internal and external support of the lamp.

For the required circular cuts, a CNC machine, typically utilized in industrial manufacturing, was employed. The lamp was adopting a shape like an onion: wider at the bottom and thinner at the top. At the time, the wood used was birch, a natural light material. The lamp was approximately 60 centimeters high and had a similar diameter. Everything was connected without using glue or nails; it was all connected using the same bending piece of wood.

Once the prototype was assembled, it looked almost like a final product, and a consultation with my teacher was conducted to obtain his perspective. The feedback was positive and mentioned that the design was very similar to other models that already existed in the Finnish market. This is how the original idea came about, unexpectedly: to turn unwanted waste into a functional and aesthetic lamp.

The redesign of this prototype was a stage of great learning since it involved both time and money. Before this product was ready to get on the market, the first batch of approximately 20 to 25 failed lamps ended up in the trash. The vast majority were discarded due to flaws that originated in design, others in manufacturing, and even in assembly.

### **Aim of the Thesis and Research Questions**

The purpose of this thesis is to identify the problems encountered during the development of the first model and to show how this lamp could have been redesigned and manufactured more efficiently if some of the principles of Lean design had been applied from the beginning until the end product.

The main question to address in this thesis is:

What would have been the results if this redesign and manufacturing had applied Lean principles from the beginning?

To help answer this question, a sub-question is formulated:

Which Lean principles are most suitable for this situation?

The focus of the thesis is mainly the comparison of designs and finding the differences in applying the principles of Lean Design and Lean Manufacturing in the process. This research is also based on my previous experience.

### **Methodology and Tools Used**

Due to the thesis's limitations, the new design will only be shown as a visual prototype, as it won't be fully made during the project's development. People will not be able to physically interact with the final lamp, but they will be able to visualize it through renderings and technical drawings.

Theoretical and practical information is used in the development of this thesis. The theoretical part is based on consulting books specialized in Lean Design and Lean Manufacturing, as well as reviewing websites and academic references available on digital platforms.

In addition, qualitative opinions will be collected through interviews with some designers and the owner of a company linked to the design area. The objective of these interviews will be to obtain feedback on the new redesign influenced by Lean principles about its feasibility, aesthetics, possible improvements, or imperfections, and thus gather valuable information about its acceptance within the professional field.

## 2 Lean Principles in Design and Craftsmanship

### 2.1 Overview of Lean Thinking

Lean thinking originated in the Toyota Production System, focusing on the philosophy of continuous improvement and waste elimination to maximize the value delivered to the customer (Ohno 1988, ix). Although this thinking was created for the Japanese automotive industry, it has already proven its applicability in very different environments, such as hospitals to design processes, and artisanal manufacturing with favourable outcomes. One of the fundamental principles of Lean thinking is to create a continuous flow of work, eliminating interruptions, downtime, and unnecessary inventory buildup. As Taiichi Ohno (1988, 4) mentioned, "*waste elimination is the key to improving productivity.*"

Eric Ries, at *The Lean Startup*, adapted this philosophy even further to the world of entrepreneurship and product development. Their approach is that learning as quickly as possible with minimal waste is more valuable than mass producing from the start. Progress, according to Eric Ries (2011, 20), is not measured by the number of products launched but by how quickly a company learns from the customer experience.

David M. Anderson (2014, 33) points out that designing with manufacturability in mind from the outset makes it possible to reduce costs, avoid errors in the introduction of the product, and accelerate its arrival to the market. This is crucial in projects such as the redesign of a lamp, where cleaner, simpler production without repetitive errors can be planned from the outset.

According to Stephen A. Ruffa, "*What marks excellent companies is not how efficiently they operate when demand is stable, and conditions are optimal. Rather, those who apply lean dynamics continue to thrive—sustaining strong profitability, growth, and innovation—even when unpredictability is constant, and change is normal.*" (Ruffa 2008, 03.)

In the artisanal field, this approach allows independent designers to apply systematic methods without sacrificing creativity. Lean Thinking drives smart decisions: modular design, efficient use of materials, and less rework. Anderson mentions that getting it right from the start is a mindset that saves enormous amounts of time, energy, and money on the citation. "*Everyone who practices DFM should adopt the motto: Do it right the first time. This advice seems obvious because no designer would begin a design expecting to redesign any part of it later. However, it is distressing how many companies routinely tolerate change orders...*" (Anderson 2014, 30.)

In short, applying Lean thinking in lamp redesign not only improves process efficiency but also reinforces the commitment to sustainability, adaptability, and constant innovation.

## 2.2 Key Concepts

### 2.2.1 Waste

Waste related to the manufacturing process, particularly in the product design part, is any activity, movement, material, or process that consumes resources without adding real value to the end customer. One of the fundamental bases of Lean thinking is to eliminate waste in its entirety, in the Japanese term, it is also known as "Muda". Systematic waste reduction is a powerful tool for improving efficiency, reducing costs, shortening lead times, and increasing product quality.

By applying this mindset from the earliest stages of design, as in the Lean redesign of a handcrafted lamp, it allows decisions to be made that minimize failures, while avoiding rework and optimizing the use of materials. Identifying waste is not just a matter of observation, it requires training the judgment of the designer or producer to detect what does not add value, even if it is standardized in their current process.

In the book *How to Implement Lean Manufacturing*, Lonnie Wilson (2010, 26) describes the seven types of waste according to the original vision of Taiichi Ohno, one of the architects of the Toyota Production System. Ohno categorized wastes into seven principal types.

These are the seven types of waste (Muda) according to Ohno:

**Overproduction:** Manufacture more units than necessary or do it before the required time. This type of waste generates excess inventory and hides other flow issues.

**Waiting:** Periods in which the process is stopped due to a lack of materials, decisions, tools, or approval. It creates an imbalance in the production line and causes a loss of time and productivity.

**Transportation:** Movements of materials or products for no reason, such as transfers between poorly located or unnecessary processes.

**Overprocessing:** Performing tasks or finishing that are not necessary for the expected performance or quality of the product. This often leads to unnecessary costs.

Movement: Physical actions of the operator (walking, turning, looking for tools) that do not add value and generate fatigue, wasted time, or errors.

Inventory: Having more materials or products than are needed at that moment. It increases the risks of damage, obsolescence, and wasted space.

Making defective parts: Products that do not meet specifications require rework or scrapping, which directly impacts production and quality costs.

Understanding and detecting these seven types of waste is the first step to implementing meaningful improvements in any design or manufacturing environment. In the case of a Lean redesign project, eliminating or avoiding this waste from the conceptual stage is essential to achieve an efficient, simple, sustainable, and viable product on a small scale.

### 2.2.2 Flow

One of the most important principles of Lean thinking is the concept of continuous flow, which refers to the uninterrupted movement of products, information, or processes from the beginning to the end of the value chain, without interruptions, waits, or blockages. In a system with good flow, materials are transformed step by step efficiently, without accumulation of inventories or unnecessary waits between stages.

In the book *Lean Thinking*, Womack and Jones (2003, 21) explain that creating flow means reorganizing production processes in such a way that each value-adding step connects to the next without interruption. "*Once the value has been precisely specified, the value stream for a specific product fully mapped by the lean enterprise, and wasteful steps eliminated, it's time for the next step in lean thinking—a truly breathtaking one: Make the remaining, value-creating steps flow.*"

This principle has a direct application in handmade design projects or small-scale manufacturing, such as in the case of the redesign of a lamp. A poorly managed flow can result in bottlenecks in assembly, downtime during drying, or interruptions during part cutting. All these elements slow down production, generate waste, and affect the final quality of the product.

At the Toyota Production System, Taiichi Ohno also links the lack of flow with waste, stating that when tasks are not well connected, more supervision, more storage space, and more error correction time are required, which negatively impacts productivity. "*Such waste is usually hidden, making it difficult to eliminate*" (Ohno 1988, 23).

Lonnie Wilson (2010, 83), in *How to Implement Lean Manufacturing*, quotes "*The shorter lead time allowed us to correct the problems because they could be found in a timely fashion and reduced the labor to rework the problems.*" Implying that improving flow not only speeds up processes but also allows errors to be detected earlier, as parts move faster through workstations. This generates a more agile response to any mistake.

In addition, David M. Anderson (2014, 281) recommends organizing the design and manufacturing process in a way that parts are easily assembled without unnecessary steps or additional complexities. He proposes that the flow can be improved if the designer thinks about the logical and simplified sequence of the assembly. It is quoted as "*Simplify assembly with fewer parts. Design for assembly without the need for any skill or judgment, and minimize manual tasks. Design easy assembly features with self-jigging parts, at each workstation, minimize part variety and standardize on one fastener per workstation.*"

In the context of a handmade workshop, implementing flow does not mean using complex automation, but simply reorganizing the workspace, times, and process logic. For example, cutting all the necessary parts before starting to bend them, preparing the templates in advance, or having the assembly space clear to facilitate movement are actions that contribute to a more natural and productive flow.

Therefore, flow is not just a technical concept of the industry; it is a principle applicable at any scale, even in the individual creation of a product such as a handmade lamp. Applying it correctly allows you to deliver faster results, with fewer errors, and above all, with greater added value perceived by the end customer.

### 2.2.3 Simplification

One of the less prominent but equally important foundations of Lean thinking is the simplification of processes. Instead of adding complexity to solve problems, Lean promotes eliminating unnecessary steps, reducing decisions, and standardizing processes, so that production flows smoothly, with fewer errors and less need for intensive oversight.

Lonnie Wilson (2010, 64) affirms, "*Process simplification is a basic concept, but is frequently overlooked by most. It is the idea of eliminating and simplifying steps in the production process. This is one of the most powerful variation reduction techniques you can employ.*" In other words, simplifying the process reduces variation. Reducing variation not only improves quality but also improves efficiency by eliminating sources of error and delay.

In his book, Wilson also points out that the concept of "Standard Work" should not be seen as an operational routine, but as a visualization and control tool for supervisors and managers. This is part of what's known as transparency: the ability to easily see the status of a process just by looking at it. This approach reduces document dependency, makes it easier to diagnose problems, and promotes a visually organized environment.

On the other hand, David M. Anderson (2014, 169–170) argues that designing products from the initial stages, considering manufacturing, allows for a significant reduction in production time, improved quality, and minimized errors. This is achieved through interdisciplinary collaboration and the application of concurrent design, an approach in which the different actors in product development work simultaneously and in a coordinated manner. Likewise, the author points out that one of the fundamental bases of the Lean approach is the reduction of the size of production batches to a single "batch size of one" unit, which eliminates the inventory in Work in Process (WIP) and improves the ability to respond to demand.

Anderson proposes that standardization and the reduction of part variety not only reduce errors and costs but also reduce the necessary plant space and inventory complexity, which is crucial for small manufacturers.

Simplification can also be approached from modular design. This allows complex products to be broken down into simpler, standardized, and reusable parts, which reduces the design burden and allows for faster assemblies with less room for error.

In short, simplifying is not doing less, but doing it better: with fewer steps, fewer decisions, fewer tools, fewer types of materials, and more clarity. For a project like this case of lamp redesign, applying simplification principles can result in fewer parts, faster assemblies, fewer molding errors, and ultimately, cleaner, more sustainable production.

production.

### 2.3 Why Lean is Relevant in Small-Scale Wood Design

Industries that applied Lean principles throughout their history, such as Nike, Intel, and Ford, among others, have proven to have positive effects, but these principles can also be applied in small-scale businesses. In the context of a designer or small shop where resources are limited and every mistake has a tangible cost, these principles can provide practical guidance for maximizing value, reducing waste, and increasing efficiency.

In the design of small-scale wooden products, such as a handmade pendant lamp, most processes are iterative, manual, and prone to mistakes in the design or execution process. In these cases, applying Lean principles can make a difference between a viable and non-viable product. Ruffa (2008, 7) indicates that small businesses that adopt a lean approach are better able to adapt to uncertainty and variation, thanks to their ability to implement rapid changes and avoid unnecessary waste.

A key aspect of small-scale design is the need to minimize the number of failures. In my own experience, manufacturing a lamp without applying Lean principles resulted in a great deal of waste of both materials and time. This is particularly relevant in manual processes, where each manufactured unit requires individualized attention.

In addition, the Lean approach stimulates modularity and simplicity of design from the earliest stages. In the context of woodworking means that there is a necessity to avoid complex shapes or cuts that make the assembly part more difficult. also, choosing a locally available material may help to reduce transportation costs, or designing shape parts that can be repeated easily in limited series without sacrificing time and quality. The goal is clear: to do more with less, without compromising the aesthetics or functionality of the product.

Finally, Lean principles allow you to make better decisions based on real data. Through analysis and collaboration with experts in the field, it is possible to adjust the design from an early stage to make it more efficient and aligned with the client's expectations. This collaborative approach is part of Lean thinking and is naturally complemented by the creative and experimental essence of artisanal design.

## 2.4 Faster, Cheaper, and Low-Waste Production

Applying these principles to the Lean redesign of the existing lamp has allowed me to rethink some parts of the process. With this new perspective, the benefits are noticed in a more agile production, a notable reduction of costs, materials, and some unnecessary steps.

One of the contributions of Lean is to change the focus from "doing more" to "doing better". Instead of producing in quantities and then storing them or correcting errors in mass, the new design allows one unit to be manufactured at a time and adjustments to be made on the spot, reducing the risk of accumulation, rework, or waste. This idea of working with minimal quantities not only improves efficiency but also allows you to respond more quickly to changes or suggestions.

The redesign also modified the structure of the lamp to prevent failures from occurring at the time of assembly. The reduction of production time per unit of lamp was also considered, in stages such as gluing, bending, drying, and wiping, which decreases labor costs and potential errors during manufacturing. In addition, by using materials that are easier to find and available on the market, sourcing is facilitated, and waiting times and shipping costs are minimized.

The principle of modular design was applied in the redesign of the lamp by simplifying its geometry and reducing the variety of parts, facilitating repeatability, manual production, and stock control.

Finally, Lean redesign is based on practical and realistic decisions. Instead of aspiring to an ideal production, it is chosen to improve what is possible, within the real conditions of a small-scale project.

### 3 Existing Lamp Design

#### 3.1 Description of the Lamp

The lamp has a bulbous shape, like a drop of water cut at both ends, composed of six vertical strips made of Birch veneer, curved mainly at two points and joined by two small pieces very similar in shape at the top and at the bottom by a piece in the shape of a circle with waves. The structure is symmetrical and visually balanced, which gives it an organic but also architectural presence.

The pressed wood pieces have a double tone, the interior surface of the lamp with a lighter color to reflect light more clearly, and the exterior surface with a darker color, adding depth and enhancing the natural beauty of the material. Its silhouette, also similar to an onion shape, generates a feeling of softness and elegance.

The open structure allows light to flow between the curves of the sheets, creating dynamic shadows and generating warm lighting. Being mounted on a wooden background, the lamp conveys a fusion between contemporary Nordic minimalism and the authenticity of the handmade. Its shape is not only decorative but also invites the touch and expresses flexibility, beauty, and elegance.

The dimensions of the lamp are 620 mm high by 530 mm wide, and it has a total weight of approximately 2 kilograms. It is composed of 6 curved arms that connect two upper pieces with a wavy-shaped lower ring. Each arm was constructed by joining six sheets of birch veneer of two different thicknesses: four units of 0.5 mm and two of 1.5 mm. Together, each arm has a final width of 90 mm, a length of 700 mm, and a total thickness of approximately 6.5 mm. The top two interior part pieces are 9mm thick, while the bottom piece is 4.5mm thick.

The lamp is designed to emit warm ambient light, ideal for creating a cozy atmosphere. This type of lighting is particularly suitable for spaces where a sense of warmth and sophistication is needed, such as dining rooms, living rooms, or rest areas. More than providing a point light, the lamp helps to define the atmosphere of the environment through a dim and natural glow.

For its construction, specific molds were used at each stage of the process: from the cutting of the sheet metal, through pressing and molding, to the final cutting and assembly. In total, the lamp consists of 11 pieces, connected with wood glue and 12 mm long nails.

What possibly makes this lamp unique is that both the design and the production were made entirely by a single person. It can be considered a completely handmade piece, made entirely by hand. A curious fact is that, despite their manual nature, only one industrial machine was used during the process, and even so, all the lamps produced maintain identical millimetric measurements.

The inspiration behind the design arose spontaneously: it was the first shape that the wood took when bent from both ends. From that initial geometry, several units were simply replicated, and the shape that generated the complete assembly was observed. For practical reasons, the light bulb was located at the top of the structure, as this allows a standard connection to be used on the market without requiring custom components.



Image 2. First redesign version

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PATENT- OCH REGISTERSTYRELSEN  
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Väiteaika alkaa mallin kuulutuksesta - Invändningstiden börjar när mönstret har kungjorts - Opposition period begins when the design has been published

Image 3. 3D view

### 3.2 Materials, Tools, and Techniques Used

The wooden parts used to produce the lamp were entirely "birch veneer", 0.5 mm and 1.5 mm thick. The thinnest sheets, due to their flexibility and softness, were always used on the outer surfaces, while the thicker ones were used on the inside of each piece. Both types of veneer were of the highest quality available on the market, to avoid seeing brown spots in the cuts, which is natural to the woods. For the exterior surfaces, sheets of different colors and species were also used, such as oak veneer, walnut veneer, and CWP colors. The upper and lower rings that connect the pieces were also made with the same materials. Only on the outer surface of the lamp was protective wood lacquer applied.

The initial model was designed to be compatible with most standard adapters available on the market, allowing the customer to install the lamp on the electrical point of the ceiling in a simple way, without requiring special adaptations.

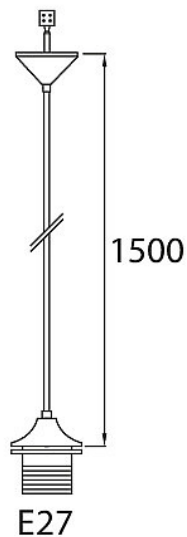


Image 4. Example of the electric standard connection

To give a curved shape to the lamp parts, the bent lamination technique was used. In this process, B3 wood glue, known for its resistance to moisture, was applied. The glued veneer was pressed inside a veneering press mold manufactured with CNC industrial machinery, which made it possible to maintain millimetric precision in terms of the shape and thickness of each piece.

piece.

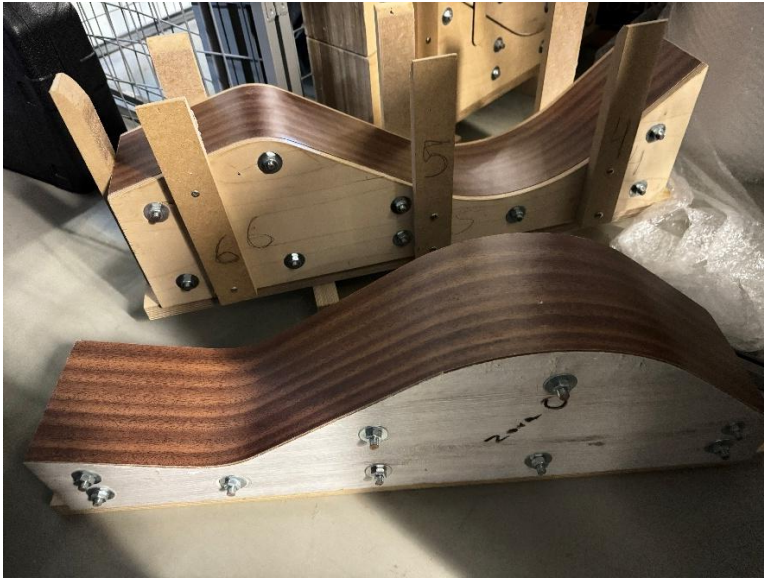


Image 5. Used veneering press mold

The curved cuts in the wooden pieces were made using three different plastic jigs, which were attached to the wood with double-sided adhesive tape to prevent any movement. Once the surface was prepared, a manual trim router-type machine was used to make the cuts.

After complete drying, the parts were removed from the veneer-pressing mold and placed in a jig, where the sides were cut with a machine called a band saw. Then, they were fed into another jig to cut the top and bottom parts, also with the same machine, ensuring that all the pieces had the same measurements.

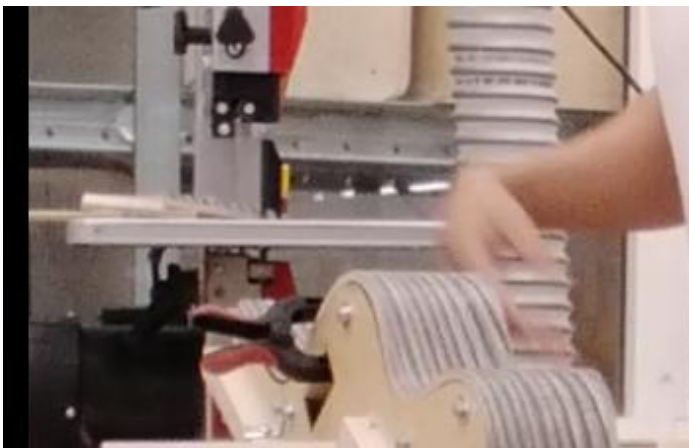


Image 6. Cutting jig model

Once the six vertical pieces were cut, the sanding was carried out. To do this, an industrial sander capable of reducing approximately 1.5 mm per side was used. Thanks to the

size of the machine, it was possible to sand up to 30 pieces simultaneously. Sanding was the last stage of the individual manufacturing process of the parts.



Image 7. Example of an industrial sanding machine

The next step was assembly. For this, a plastic jig was used where all the pieces of the lamp fit together at the same time, precisely. The assembly consisted of gluing each piece together using wood rubber and securing the joints with a machine called a Pin Needle, which provided enough resistance even after carrying out impact tests by releasing the lamp from two meters. These tests were only carried out on the first units as endurance tests.

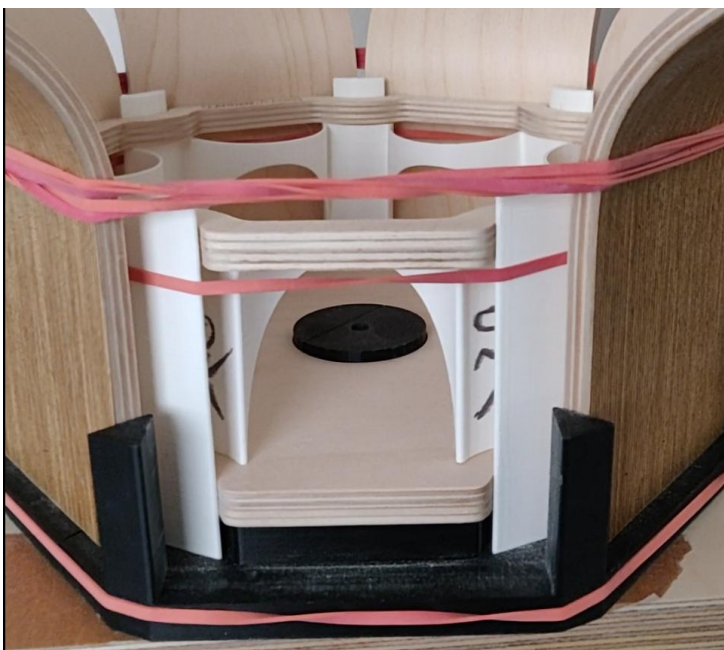


Image 8. Assembly plastic jig

Finally, at two points in the process, the cutting with the band saw and the use of the industrial sanding machine, potential risks were identified due to the power of the machines and how sharp the blades were. However, applying all the safety measures learned during the studies at the Salpaus school, the work was carried out in a safe and controlled manner.

### 3.3 Manufacturing Time and Cost

Considering that only one person made the lamp, here is a list of the detailed times:

- 25 minutes cutting the birch sheets to fit the veneering press mold
- 20 minutes sanding the interior surfaces of the vertical pieces
- 45 minutes bent lamination process
- 20 minutes cutting the curved pieces
- 10 minutes applying lacquer
- 1 hour producing one small and one large ring
- 15 minutes assembling the lamp
- 5 minutes final touches and quality check

The total production time is 3 hours and 20 minutes per unit. For the material cost per lamp (excluding taxes), below is a breakdown of the estimated cost of the materials needed to manufacture a lamp, considering retail purchases in 2025:

- €18.79, 18 units of 120 mm x 725 mm, 1.5 mm birch veneer
- €15.66, 18 units of 750 mm x 120 mm, 0.5 mm birch veneer
- €9.49, 6 units of 750 mm x 120 mm, different CWP veneer (outer surface)
- €6.00, 2 units of 500 mm x 500 mm, 1.5 mm birch veneer
- €7.50, 3 units of 500 mm x 500 mm, 0.5 mm birch veneer
- €4.3, wood glue
- €0.81, thin nails (for use with Pin Needle machine)

The estimated total material cost per unit is €62.28. In addition to the final production cost per unit, the average gross salary of a carpentry worker in Finland is between €15 and €25/hour, depending on experience. For this calculation, use an average gross salary of 20 €/hour.

The total production cost of the lamp, determined using the formula  $\text{Total Cost} = (\text{Working Hours} \times \text{Price per Hour}) + \text{Material Cost}$ , amounts to 128.88 euros, based on 3.33 hours of labor at 20 euros per hour plus 62.28 euros in material costs.

### 3.4 Challenges Identified in the Process

During the manufacture of the first units, multiple problems were produced and identified regarding the design, such as in the production and assembly process of the product.

One of the errors detected was the design of the interior small rings, which turned out to be too narrow. This caused, during assembly, the small nails to protrude towards the surface, exposing the sharp metal, with the risk of causing cuts in the skin. This situation not only compromised the safety of the user but also revealed an assembly failure that needed to be corrected.

Another important design error was the angle that the two pieces made when applying the glue and using the mini nails. The natural direction of the wood and the angle of entry of the nails meant that they often did not follow a straight path and came out of the surface. In addition, at the beginning, the mistake was made of assembling the parts without using jigs, which caused variations in the separations between each part. As a result, the lamp lost symmetry and proportion, and the light from the interior spotlight filtered unevenly through irregular slits, affecting the aesthetics of the design.

As for the materials, another problem was the choice to use pre-manufactured birch plywood. Although its price was equal to or even higher than birch veneer, its quality did not hold up over time: after a few months, the material began to yellow, while birch veneer retained its light, off-white color. In addition, the mistake was made of combining birch veneer from two different distributors, which resulted in visible differences in the color and texture of the interior of the lamp, breaking the aesthetic uniformity.

Another inconvenience is not letting the pieces dry inside a shape holder. By leaving them to dry in the open air without shape control, the curved sheets adopted different shapes, and a set of parts with notable variations in curvature and size was obtained, which made uniform assembly difficult.

The initial design of the large ring was also inefficient from the point of view of the use of materials. Its large size generated a lot of waste, even after trying to recover material by cutting small pieces from the inside. In addition, the veneering press mold is used for only one piece at a time, resulting in a significant loss of time and material.

At an early stage, an attempt was also made to sand the 6 vertical pieces once they were already assembled, which proved extremely difficult due to their curved shape. Another technical mistake was applying 1.5mm birch veneer to the inner surface: its thickness

caused it to crack easily, leaving loose splinters that compromised both safety and the final finish.

These problems were gradually solved through small modifications in the design, as well as with the creation of specific jigs for each stage of the process. These improvements made it possible to reduce errors and speed up the manufacturing process.

## 4 Lean-Based Redesign Strategy

### 4.1 Lean Objectives

The main objective for the redesign is to apply Lean principles to improve the efficiency of the production process, reduce costs, and eliminate waste, both material and time. From the analysis of the original model, several points of improvement were identified:

Reducing material usage represents one of the most significant direct cost-saving measures in any manufacturing process. Therefore, minimizing the quantity of materials used directly leads to a decrease in overall product costs. In addition, adopting an assembly model in which the customer assembles the product contributes to reducing production time. Furthermore, manufacturing time is shortened through optimization of critical stages such as shaping, drying, and cutting. Moreover, the use of more accessible and standardized materials facilitates supply logistics and reduces cost; premium options, such as CWP veneer, will not be used to maintain affordability. As a result, work-in-progress (WIP) inventory is reduced through a one-day production cycle using a batch size of one. Additionally, the design is made adaptable to manual manufacturing, eliminating the need for expensive tools. Ultimately, this lean-oriented approach aims not only to optimize operations but also to rethink the entire design process concerning manufacturing efficiency, sustainability, and responsiveness to end-user needs.

### 4.2 Ideation: Visual Exploration & Design Goals

The ideation phase focused on finding new design possibilities and structures that would maintain the identity of the original product, but with more efficient manufacturing. Through visual references, existing products, and contemporary design examples, cleaner, the goal was to develop cleaner, lighter, and more easily reproducible products.

The design objectives were:

- Maintain the organic design shape that suits the natural wood material
- Ensure a solid structure that makes the assembly time easier
- Allow each part of the design to fulfil a structural and aesthetic function
- Simplify the bending process, allowing smooth bends without specialized tools

### 4.3 Sketches and Concept Development

This section shows the hand-made sketches of the lamp. The main objective was to find new ways that go according to the ideation stage.

During this phase, different geometries, cutting systems, and assembly forms were explored, considering both the limitations and problems observed in the original design. Through sketching and iteration, it was possible to visualize alternatives, compare, and move toward a clearer and more functional solution.

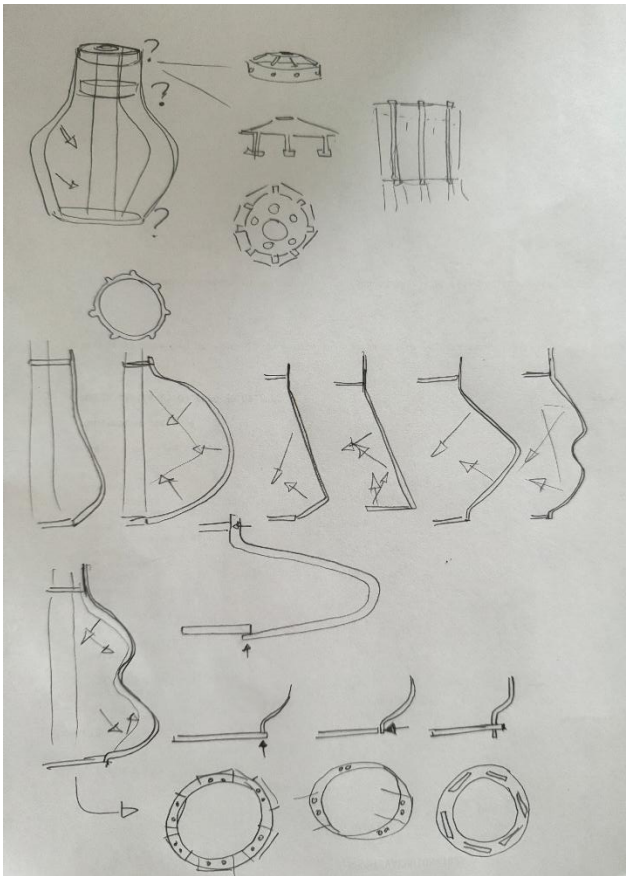


Image 9. Redesign sketches process

### 4.4 Form, Function, and Simplicity

Final design decisions were made by evaluating proposals that sought to meet the objectives of the established Lean principles. A focus on formal simplicity was prioritized, where each curve, cut, or union responded to a clear function.

Shape: Maintaining the essence of the original model, a very similar but thinner fluid shape was chosen, which allows, without the need for a complex veneering press mold, to bend larger pieces easily.

Function: Each piece of the selected design has a purpose, but at the same time maintains the original style.

Simplicity: The number of parts was minimized to the minimum possible, with the redesign focusing not only on the manufacturing process but also on simplifying the assembly for the end user and reducing the packaging size for easier shipping. Additionally, some complex components were redesigned to be produced using 3D printing, replacing manual work to save both time and production costs.

These decisions allow for a more controlled, faster, and adaptable manufacturing to the demand while maintaining a careful aesthetic.

## 5 Simulated Prototype

### 5.1 Simulated Production Plan (Estimated Time and Cost)

To create the six long pieces that make up the lamp, a wooden press mold is manufactured using the CNC industrial machine. The wooden block is of sufficient dimensions to cover the size of the pieces, along with a surplus destined for the subsequent cuts. For the wooden piece production, three sheets of 0.5 mm and two sheets of 1.5 mm-thick birch veneer material. Wood glue will be applied between the layers, and the assembly will be placed inside the veneering press mold, and then pressure will be applied. It will be necessary to allow it to dry for several hours before transferring the parts to second-cutting jigs.

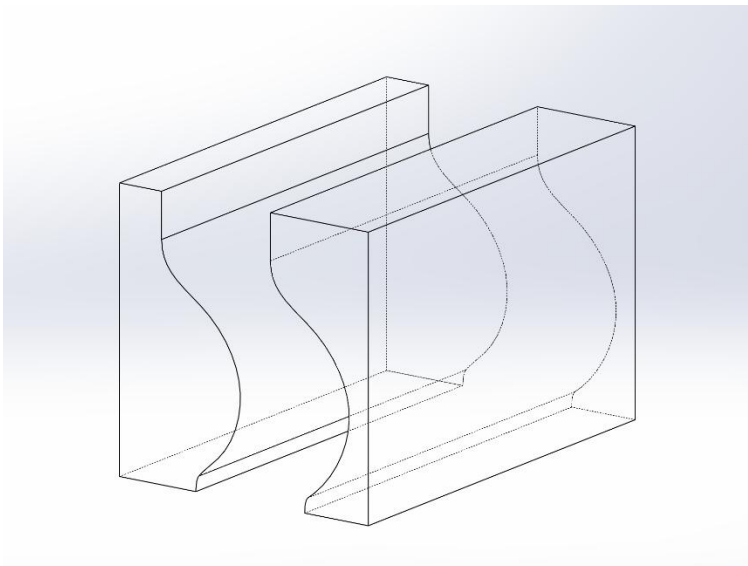


Image 10. Visualization of a bigger veneering press mold

The next process is the top, bottom, and side cuts, which will be carried out using a table saw such as the Hawk Duab PM250-30, a model capable of cutting the parts continuously. After all the wooden parts are cut, proceed to sand the edges for a softer touch. For the creation of circular holes with a diameter of 4 mm, two different models of drilling jigs will be used, which will be used in combination with a vertical drilling machine, such as the “Einhell TE-BD 750 E model”. These templates will allow the drill bit to be positioned precisely in the same place on all parts.

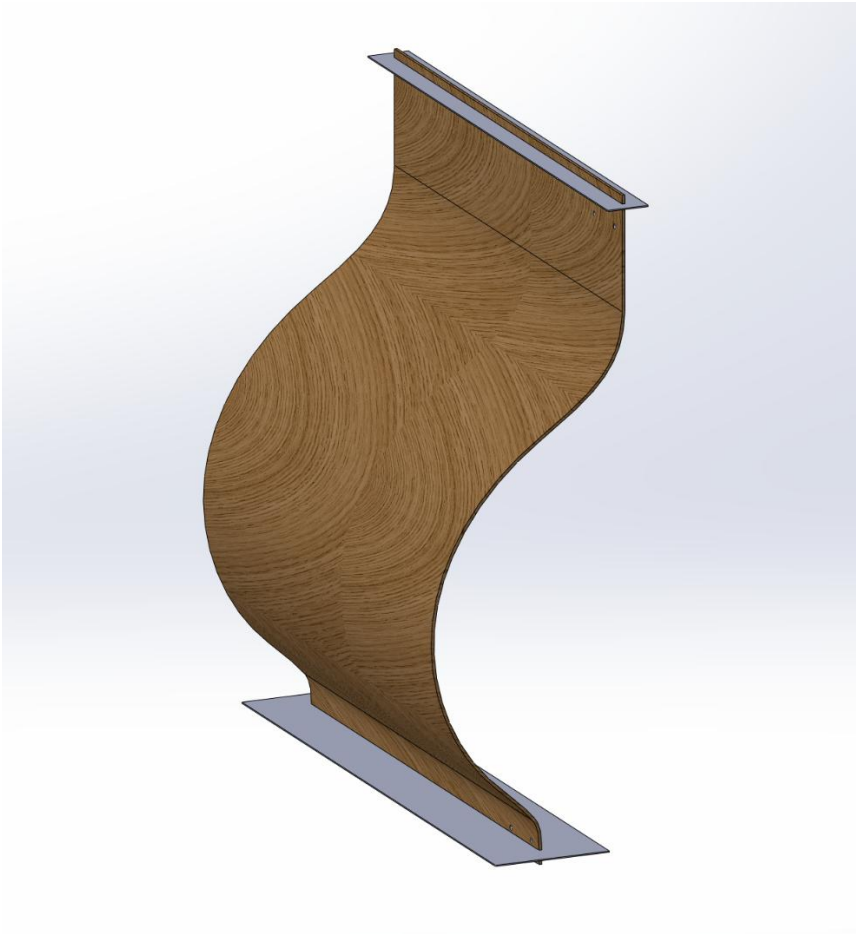


Image 11. Example of the 2 horizontal cuts

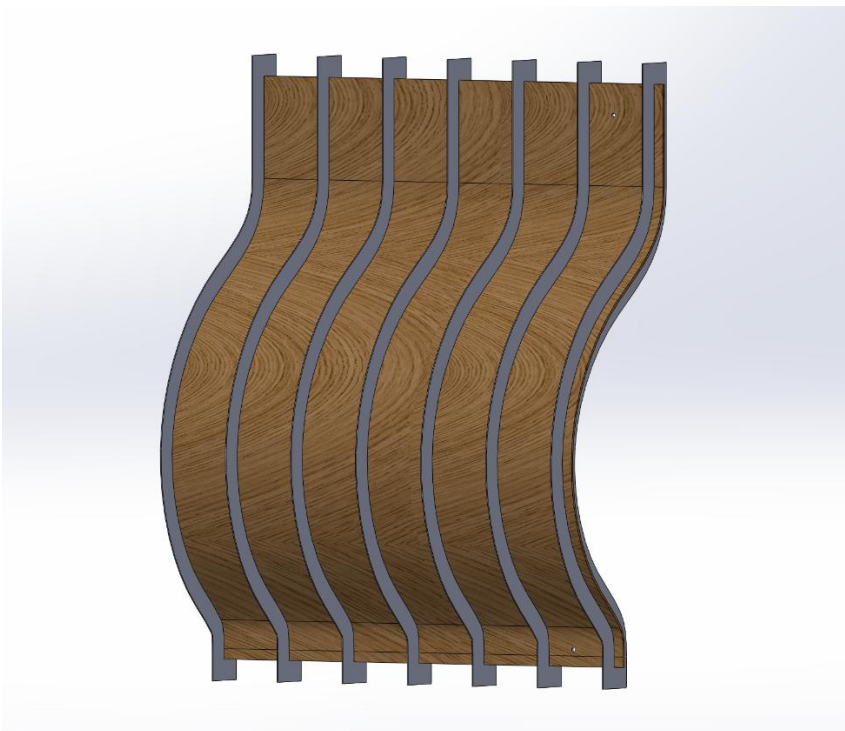


Image 12. Example of the vertical cuts

The two rings, the larger lower one and the upper one, as well as the 24 buttons of 4 mm diameter that will be used for the press-and-pressure connection of the parts, will be manufactured by 3D printing using machines such as the “Creality K2 Plus”, which has a printing area of 350 mm × 350 mm × 350 mm. After this, there is no assembly process.

Here is a list of the detailed times for this new design production:

- 15 minutes, cutting the birch sheets to fit the veneering press mold
- 10 minutes, sanding the interior surfaces of the vertical pieces
- 15 minutes, bent lamination process
- 15 minutes, cutting the curved pieces
- 10 minutes, drilling holes in the pieces
- 5 minutes, setting the Printer to one small and one large ring

The total production time is 1 hour and 10 minutes per unit. For the material cost per lamp (excluding taxes), below is a breakdown of the estimated cost of the materials needed to manufacture a lamp, considering retail purchases in 2025:

- €6.48, 2 units of 450 mm x 600 mm, 1.5 mm birch veneer
- €7.83, 3 units of 600 mm x 450 mm, 0.5 mm birch veneer
- €10.00, 500 g of PLA filament

The estimated total material cost per unit is €24.31. For the production cost per unit, the average gross salary of a carpentry worker in Finland is between 15 and 25 €/hour, depending on experience. For the calculation, an average gross salary of 20 €/hour is used.

The total production cost of the lamp, calculated using the formula  $\text{Total Cost} = (\text{Working Hours} \times \text{Price per Hour}) + \text{Material Cost}$ , results in 47.64 euros, based on 1.16 hours of labor at 20 euros per hour plus 24.31 euros in material costs.

## 5.2 Technical Drawings, Exploded Views

This section presents the technical drawings detailed in millimeters to accurately document each of the parts that make up the final design, such as the curved arms, the upper piece, and the lower ring.

The exploited views complement this information by showing the spatial relationship between the elements, making it easier to understand the assembly and the joining points.

In addition, a complete technical drawing of the assembled lamp is presented, which allows you to visualize the final size and how the parts are integrated.

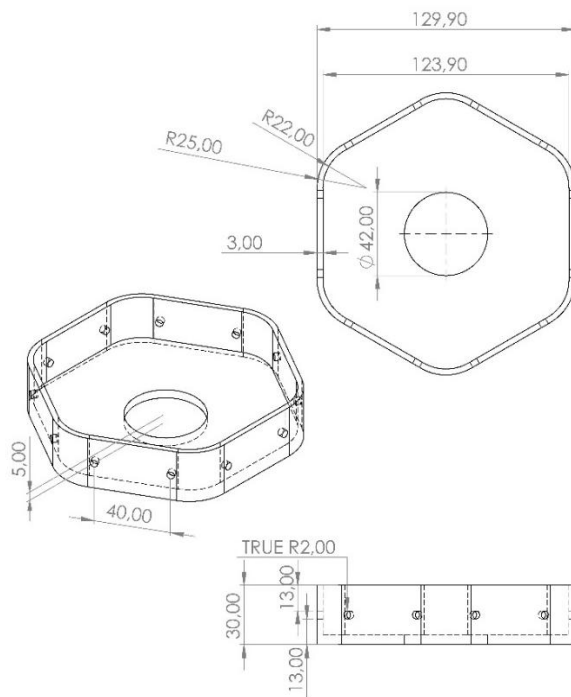


Image 13. Base lamp piece made by 3D Printing

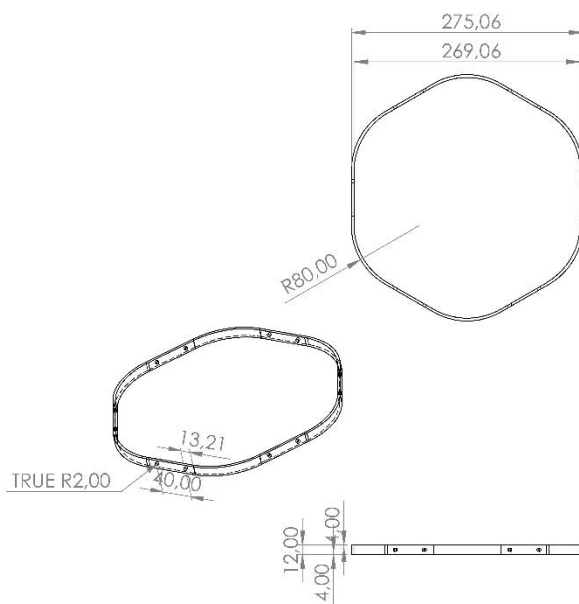


Image 14. Big ring made by 3D printing

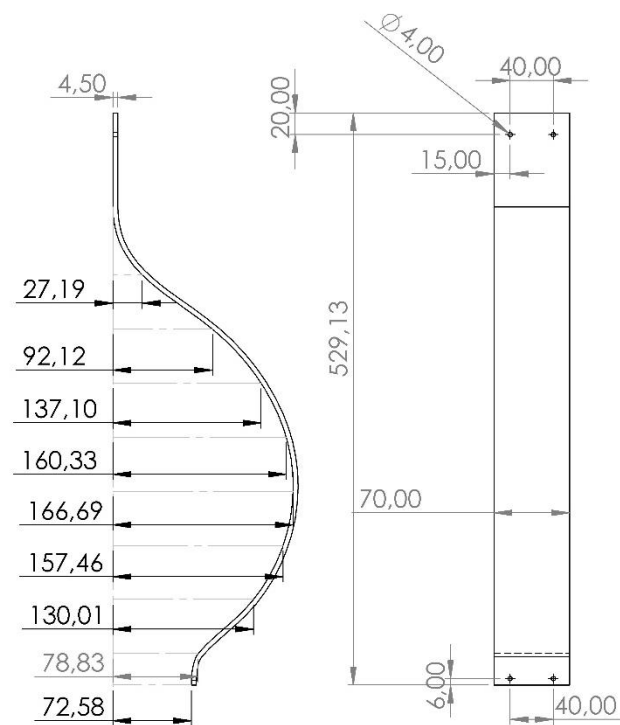


Image 15. Birch veneer piece

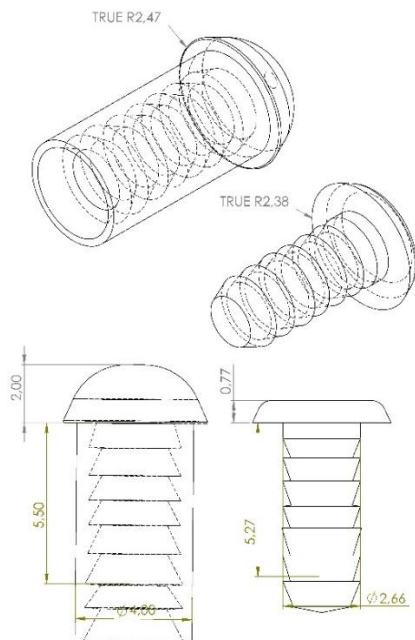


Image 16. Plastic connectors made by 3D printing

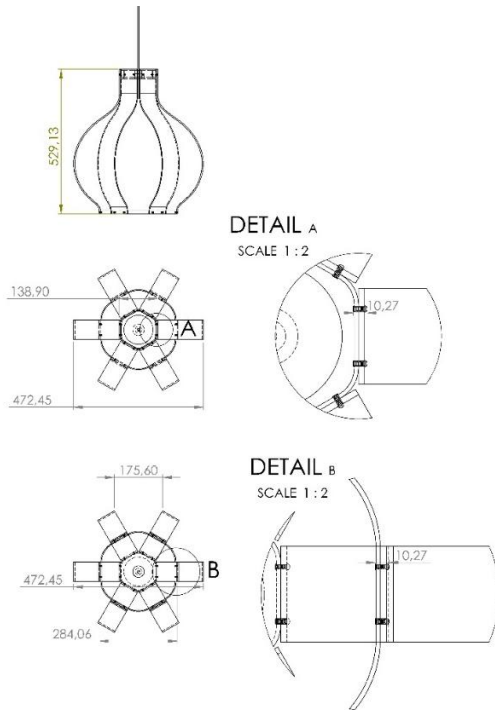


Image 17. Assembled lamp

### 5.3 3D Model, Rendered Images of Final Prototype

This image presents a top view of the lamp, clearly revealing its overall form. From this angle, the construction and assembly of the lamp become more apparent, particularly highlighting the distinctive design of its arms. The image allows for a better understanding of both the shape and structural composition of the lamp.



Image 18. Isometric view

This image offers a frontal view of the pendant lamp, capturing its overall appearance. From this perspective, the lamp's organic character becomes evident. The design successfully preserves the original organic flow, even within the constraints of the lean re-design approach.



Image 19. Front view

This bottom-up view highlights the lamp's unique plastic ring and organic form. It reflects the typical user perspective, as pendant lamps are usually seen from below in spaces like living rooms or above tables, making this angle essential for evaluating visual impact.



Image 20. Isometric view from the bottom

The bottom part of the redesigned lamp embodies Lean simplicity, clean, functional, and free of unnecessary complexity. It reduces material use while maintaining an elegant, intentional form.

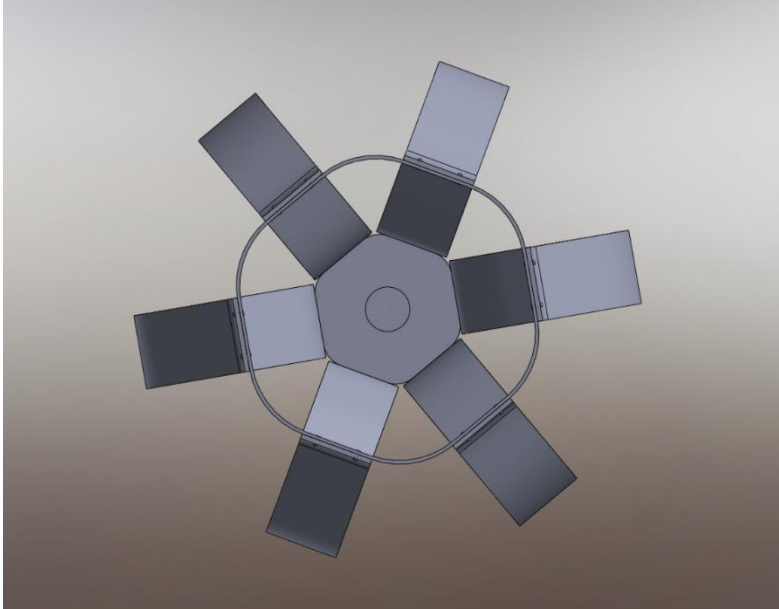


Image 21. Bottom view

This image shows the lamp in a real-life living room setting, demonstrating how it integrates into a domestic environment. Such context is crucial, as it reflects the final product in actual use, highlighting its aesthetic and functional role within the home.



Image 22. Render picture A

This image presents a nighttime demonstration of the lamp, showing how its light reflects on surrounding walls. It offers insight into the atmosphere the lamp creates in the evening, revealing both the lighting effect and the mood it establishes in the space.



Image 23. Render picture B

#### 5.4 Expected Waste Reduction and Assembly Improvements

Several improvements were implemented in the production process, following Lean principles, such as waste reduction, simplifying processes, and increasing efficiency. The top and bottom rings of the lamp were previously made fully manually from wood, this new version is produced by 3D printing with PLA plastic. This change eliminated material waste caused by the undulating and irregular shape of these parts and reduced the hours of manual labor. In addition, the new printed parts incorporate a small plastic connection system, which eliminates the use of 12mm metal nails and simplifies assembly. The thickness of the wooden arms was also reduced from 6.5 mm to 4.5 mm, eliminating two internal layers of birch veneer (one 1.5 mm and one 0.5 mm), which made it possible to reduce weight and material use without compromising structural strength. The cutting process was optimized; instead of cutting each piece separately, the six pieces are now obtained through continuous cuts, which reduces both material waste and manufacturing time. Finally, a structural part located in the middle of the lamp was removed, thus decreasing the total number of components and further simplifying the assembly process.

## 6 Expert and Peer Feedback

### 6.1 Interview Setup and Methods

To evaluate the Lean redesign of the lamp, semi-structured face-to-face interviews were conducted with ten professional designers and one entrepreneur who was a former lamp salesman. The purpose was to obtain concrete opinions on the aesthetic, functional, and manufacturing aspects of the product, as well as on its consistency with Lean principles and its acceptance in the market. The interviews were developed based on pre-established questions, providing participants with the possibility of giving structured answers and providing free comments. The questions were grouped into five main categories:

About the Product, participants were asked for their first impression of the shape and aesthetics of the redesigned lamp. About Manufacturability and Production, it was assessed whether the new design seemed easier or faster to manufacture and whether the choice of materials and construction methods was suitable for small-scale production. About Lean Principles, Participants were asked to indicate whether the redesign showed clear evidence of waste reduction in materials, time, and resources. Also, user Perception, participants were asked for their opinion on how customers would perceive the value of the redesigned lamp, and how the plastic parts can affect its perceived quality or desirability. And the last, open Question and Improvements, the participants were invited to suggest aspects that they would improve in the new design.

Interviews were conducted individually, and all feedback was documented and then analysed to identify common patterns, strengths, and improvement areas for the redesigned product.

### 6.2 Feedback from Designers and a Company Owner

A few key comments were collected on different aspects, aesthetic, functional, manufacturability, and the application of Lean principles.

Aesthetic Comments:

- Most designers agreed that the new design managed to preserve the original aesthetic intent. The lamp maintains its organic and elegant shape, despite structural optimizations.
- Some participants mentioned that the introduction of plastic components slightly reduced the perception of "luxury" compared to the original wood version.

- Overall, the group positively valued the way the new design maintained the lines of the original design.

#### Functional Comments:

- Most participants reacted to the reduction of pieces in the new structure, in addition to being more logical and practical.
- The designers stressed that the simplification of the assembly process is good.
- Many claimed that the modularity of the design, which makes it easy to replace or adjust parts, was a good improvement.

#### Comments on Manufacturing and Lean Efficiency:

- The company owner and several manufacturing-oriented designers agreed to the reduction of unnecessary parts and steps.
- Some participants assume the design adjustments took that look aspect under Lean principles consideration.

#### Suggestions for Improvement:

- Some designers recommended exploring more eco-friendly alternatives to the use of plastic components.
- Some participants will add different colours.
- It was suggested to develop a second, more premium version.
- Many responded that eliminating the curves on the lower rind might be slightly easier to manufacture.
- Some participants answered that this new design can be received, but with a lower quality feeling on the market.
- One participant proposed making small adjustments to the details of the joints to make the assembly even faster and stronger.

## 7 Comparative Analysis

### 7.1 Side by Side Visual Comparison (Photos/ Renders)

The following front-view image illustrates that the redesigned lamp retains the overall form of the original model. However, a notable difference lies in the curvature angles, which are now more open. This adjustment results in a broader arc that terminates at a nearly vertical angle. As a consequence, the assembly process with the larger lower ring is significantly simplified and faster.



Image 24. Comparison A

This image highlights a change in the lower ring, specifically the incorporation of a plastic component. Despite the material alteration, the original stylistic identity is preserved. The design of the new plastic element was intentionally developed to visually integrate with the rest of the lamp, maintaining aesthetic continuity and elegance.



Image 25. Comparison B

The following bottom-view comparison of the two lamps reveals the elimination of the sharp angles, which was a major contributor to excessive material waste and prolonged assembly time. In contrast, the new plastic component in the redesign is clearly integrated into the overall form, presenting a more cohesive and contemporary appearance without compromising visual harmony.

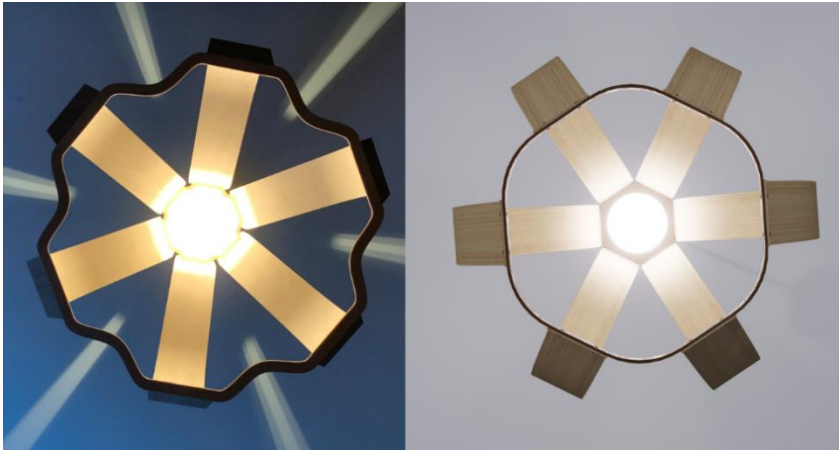


Image 26. Comparison C

## 7.2 Efficiency Gains

The Lean redesign of the lamp resulted in measurable efficiency gains across three key areas: production time, manufacturing costs, and material waste. The following table summarizes the improvements achieved:

Aspect	Original Lamp	Lean Redesign	Efficiency Gain
<b>Production Time</b>	Longer due to complex assembly and drying steps	Shortened thanks to simplified structure and reduced steps	Approx. 30–40% faster
<b>Manufacturing Cost</b>	Higher, due to more material use and a labor-intensive process	Lower, with optimized material use and faster assembly	An estimated 25–30% cost reduction
<b>Material Waste</b>	More waste due to off-cuts, defective parts, and extra inventory	Less waste through better part design, batch size of one, and minimal off-cuts	Significant waste reduction (~40–50%)
<b>Inventory (WIP)</b>	High, with multiple unfinished units between steps	Minimal, with unit-by-unit production flow	Near-zero WIP
<b>Repair &amp; Replacement</b>	Difficult, non-modular construction	Easier due to modular design and standard parts	Simplified maintenance

Image 25. Manufacturing differences

Category	Re-Design	Original Design
Production Steps		
Cutting birch sheets	15 minutes	25 minutes
Sanding interior surfaces	10 minutes	20 minutes
Bent lamination	15 minutes	45 minutes
Cutting curved pieces	15 minutes	20 minutes
Drilling / Lacquering	10 minutes (Drilling)	10 minutes (Applying lacquer)
Producing rings	5 minutes (Printer setting)	1 hour (Manual production)
Assembling	-	15 minutes
Final additions & Quality check	-	5 minutes
Total Production Time	1 hour 10 minutes (1.16 hours)	3 hours 20 minutes (3.33 hours)
Material Costs		
Birch veneer	€14.31	€49.94
PLA filament / Other materials	€10.00 (PLA filament)	€5.11 (Glue and nails)
Total Material Cost	€24.31	€62.28
Labor Costs		
Hourly wage	€20/hour	€20/hour
Labor cost per unit	€23.20	€66.60
Total Production Cost	€47.64	€128.88

Image 24. Data comparison between both products

### 7.3 Aesthetic and Functional Improvements

Based on the redesign applied under the principles of Lean Design, subtle changes were made in the appearance, but significant in the structure of the lamp. Aesthetically, the product retains practically the same original design, which was one of the main objectives: to achieve a more efficient form of production without altering its visual identity. Although the design maintains its characteristic elegance, the incorporation of some plastic pieces could generate mixed perceptions regarding the level of sophistication. However, in general terms, the style remains consistent with the initial proposal.

From a functional point of view, the improvements were much more evident. The redesign had noticeable consequences on both the production and assembly processes, making them faster and easier. In addition, logistical aspects such as storage and shipment of the product were improved, contributing to a clear reduction in manufacturing costs. The new approach also facilitates future repairs and replacement of parts.

Overall, the redesign achieves a solid balance between aesthetic quality and structural and functional improvements, following a Lean approach that prioritizes beauty, simplicity, efficiency, and elegance.

## 8 Conclusion

The redesign project using Lean principles made it possible to demonstrate that it is possible to improve both the production process and the final product, without compromising much on aesthetic or functional quality.

With the elimination of waste, the simplification of processes, and the optimization of resources, it clearly facilitated a reduction in manufacturing times, in the cost of materials, and the complexity of assembly. The change from handmade components to 3D printed parts, the reduction of the thickness of wooden parts, and the elimination of unnecessary structural elements are examples of how the Lean philosophy can be applied on a small scale.

On an aesthetic level, the redesign maintained a shape similar to the original lamp and with it the sensations it transmits, but this time incorporating more efficient and sustainable solutions. From a functional point of view, the new version not only facilitates assembly but also opens the possibility of more flexible production that can be adapted to real demand by optimizing resources. In conclusion, this project demonstrates that integrating Lean principles into product design is not only feasible but also beneficial. Not only do you get more efficient and economical results, but you also promote a more conscious, sustainable, and value-oriented way of designing.

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## Appendix 1. Questions for the interview with designers

### A. About the Product Itself

(Design and Functionality):

What is your first impression of the redesigned lamp in terms of form and aesthetics?

### B. About Manufacturability and Production:

From a production point of view, does the new design seem easier or faster to manufacture?

Do you think the material choice and construction methods are appropriate for small-scale production?

### C. About Lean Principles (Efficiency, Waste, Simplicity):

Do you see evidence of reduced waste (materials, time, resources) in the redesigned product?

### D. About Market and User Perception:

How do you think customers would perceive the value of this redesigned lamp?

Would the simplifications impact the perceived quality or desirability of the lamp?

### E. Open-Ended and Improvement:

If you could change one aspect of the new design, what would it be?