



UNSTAPLED AND REFOAMED

REDESIGNING COUCHES FOR DISASSEMBLY, REUPHOLSTERY AND FOAM REPLACEMENT

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This thesis marks the final step of my Master's degree in Integrated Product Design at the Faculty of Industrial Design Engineering at TU Delft. From February to June 2026, I immersed myself in the world of couches, from factory floors and disassembly halls to foam blocks, upholstery details and circular furniture systems. This report brings together the research, design work and prototypes developed during these months.

I would like to thank my supervisory team, Jotte de Koning and Bas Flipsen, for your guidance, inspiration, critical questions and support throughout the project. I especially appreciated your encouraging messages on Signal during the prototyping phase, as well as the moments when you helped me slow down, take a break and keep the project manageable.

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SUMMARY

Couches are often discarded while many of their components still have value. The frame, suspension and inner structure can often last longer than the upholstery and foam, but current couch constructions make these wear parts difficult to access and replace. Foam is commonly glued to the frame, while upholstery is fixed with a combination of staples, zippers, stitching, velcro and other connections. This makes refurbishment labour intensive and reduces the feasibility of producer-based take-back.

This graduation project investigates how couch design can enable faster and more feasible refurbishment. The project was carried out with The Bin and Dutch Quality Group. The Bin provided the broader system perspective through the ReUse Alliance, while DQG served as the case company for product analysis and prototyping. The context analysis showed that textile and foam have a high environmental impact and are also the first components to wear out. Interviews with stakeholders confirmed that reuse and refurbishment are preferred over recycling, but that logistics, costs and product design currently limit circular furniture systems. Disassembly and reupholstery mapping of a DQG couch showed that the main barriers are the removal of upholstery and glued foam.

Based on these insights, two design directions were developed. The first is a foam compartment concept, where the seat cushion foam is divided into smaller blocks so only locally sagged parts need to be replaced. The second is a pullcord cover, where upholstery is tensioned reversibly with a cord instead of permanent fastening.

The final demonstrator combines these principles in one cushion. It shows that foam can be made accessible without destructive actions and that local block replacement can reduce material use during refurbishment. The comparison indicates that one seat cushion refurbishment could be completed 12 minutes faster, 45 to 50 percent cheaper and use 67 percent less new foam when only one third of the cushion needs replacement. However, the current demonstrator also increases first production cost, mainly due to the felt inlay and pullcord system.

The project concludes that the exact concepts are not a universal solution for every furniture producer. Their strongest application lies in high quality B2C couches with enough residual value to justify refurbishment. More broadly, the project shows that future couch design should make wear components easier to access, remove, replace and trace, so refurbishment can become a realistic activity for producers.

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1. INTRODUCTION

1.1 The problem of discarded couches

Couches are increasingly discarded and incinerated, causing unnecessary loss of material and product value. Across Europe, the furniture sector generates approximately 10.78 million tonnes of waste annually (CORDIS, European Commission, n.d.). At the same time, furniture lifespans are decreasing. Where couches remained in use for approximately 14 years around 1985, estimates from 2019 suggest an average lifespan of only six years (Intven et al., 2022).

This shift is often associated with the rise of fast furniture, in which products are optimized for low cost, trend sensitivity and rapid replacement rather than long term use. In the Netherlands, around 14 million furniture pieces are discarded each year, while only a limited share is reused or recycled (NPO Start, 2026). Upholstered furniture is especially difficult to process, because couches are made from multiple material layers that are often glued, stapled or stitched together. Additionally, research by The Bin showed that a large share of couches arriving at municipal waste collection points could still be reused or refurbished after relatively small interventions (see *Appendix P-A on page 119*).

1.2 The need for refurbishment

Circular strategies such as reuse, repair and refurbishment aim to retain product value for longer before materials are recycled or incinerated. For upholstered furniture, refurbishment could be a valuable strategy because it keeps products in use and preserves more value than material recovery alone.

However, refurbishment also needs to be feasible in practice. It depends on logistics, labour, product quality, business models and the way products are designed. Circular interventions will only be adopted when they fit existing production

and service systems and create value for both producers and users.

Upcoming Extended Producer Responsibility regulations are expected to further increase the urgency of this transition. If producers become more responsible for the waste phase of their products, design for repair, refurbishment and disassembly will become increasingly relevant (Zandbergen et al., 2023).

1.3 Project partners

This graduation project was carried out in collaboration with The Bin and Dutch Quality Group.

The Bin works on accelerating circular transitions in the furniture sector through the ReUse Alliance. Their work focuses on chain collaboration, reuse, refurbishment and the organisation of return flows after the consumer phase. Within this project, The Bin provided the broader system perspective and connected the research to ongoing discussions around furniture waste, reuse and future producer responsibility.

Dutch Quality Group is a Dutch furniture manufacturer behind brands such as Design on Stock and EYYE. DQG produces high quality upholstered furniture in the Netherlands and served as the case company for this project. Their production knowledge, factory access and product data made it possible to analyse a real couch construction and test design interventions within a realistic manufacturing context.

Together, these partners allowed the project to connect system level questions about circular furniture with product level questions about couch design.

1.4 Aim of the project

This project investigates how interventions can

enable producers to repair and refurbish their own couches. By researching the market, product and current reupholstery steps, opportunities and barriers are identified that enable or prevent refurbishing from happening.

1.5 Report structure

The report starts with a context analysis of upholstered furniture. It first explains how couches are built, how they are produced, which parts have the highest environmental impact and where the main circularity barriers are located.

The analysis continues with researching the Dutch furniture system through interviews, stakeholder insights, system mapping and upcoming policy developments. Additionally, the disassembly and reupholstery of a DQG couch in detail are analysed. These insights are translated into design principles and concept directions. The analysis phase led to a refined problem definition and research question focused on product design for refurbishment.

The exploration phase shows the development of ideas that address this refined research question. The ideas are clustered and evaluated with product designers and production leads from DQG, after which two concepts are chosen.

The two concepts are worked out in the prototyping phase, where prototypes were used to test ideas, learn from their behaviour in context, and refine the design direction through Research through Design (RtD).

The final deliverable is a tangible demonstrator cushion intended to communicate how upholstered furniture could be designed for easier refurbishment. It can also be used at DQG as a test object to evaluate refurbishment steps, handling and production feasibility.

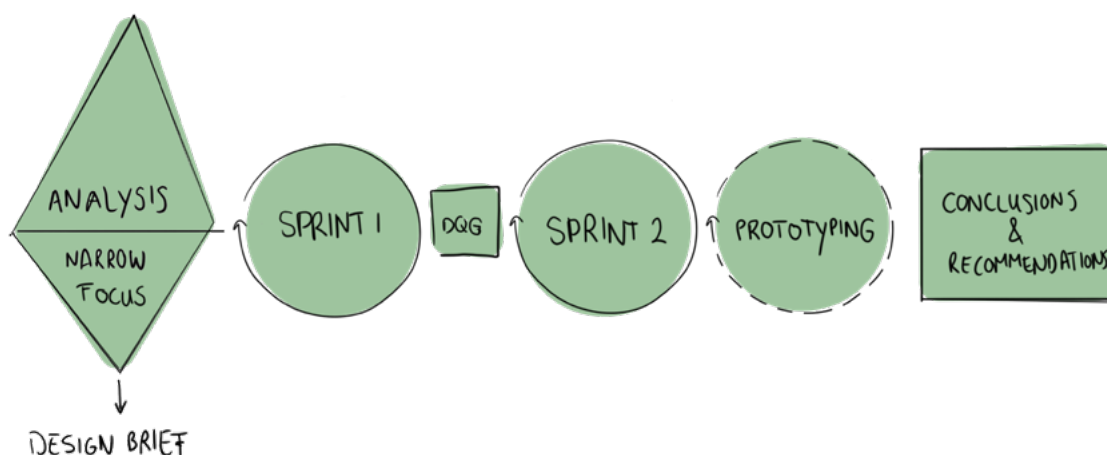


Figure 1: Project outline



Picture from Demontagehal Almere (13-02-2025)

ANALYSIS

This chapter aims to analyse the context of upholstered furniture in the Dutch furniture sector. It starts by analysing the architecture of the couch, production methods and pain points in design. Each chapter ends with a short conclusion of barriers and opportunities for refurbishing.

Afterwards, the furniture sector is analysed. Through semi-structured interviews a thematic analysis is performed to create an overview of desires and struggles stakeholders face. This is then translated into a system map.

It concludes with analysing the selected couch through disassembly mapping and hotspot mapping, in order to identify which components, connections, and actions currently form the main barriers to refurbishment.

2. WHAT IS A COUCH MADE OF?



Figure 2: Wooden parts of the couch



Figure 3: Wooden frame of the couch



Figure 4: Nosag springs before assembly

2.1 Introduction

To understand why couches are difficult to repair or refurbish, the product architecture first needs to be analysed. Upholstered couches consist of multiple material layers that are assembled in a fixed sequence during production. These layers determine which parts of the couch carry structural loads and which parts mainly provide comfort or aesthetics.

This chapter therefore analyses the architecture of upholstered couches.

2.2 Structure of the couch

A couch consists mainly of five materials: wood, metal, foam, fabric or leather and other connecting materials such as plastics. The structure of a couch consists of five main parts:

1. The frame
2. The suspension layer
3. The foam layer
4. The upholstery layer
5. The connection system

In *Figure 5* the average material composition of a couch is visualized (Des Abbayes & Mignon, 2016).

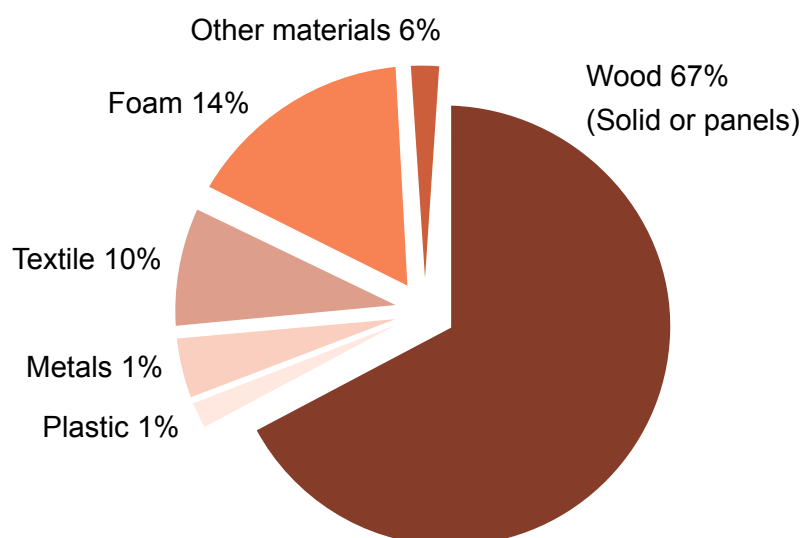


Figure 5: Pie diagram material composition couch

WHAT IS A COUCH MADE OF?



Figure 6: Couch before gluing foam on frame



Figure 7: Couch in foam gluing cabin



Figure 8: Dacron layer applied

2.2.1 The frame

The main function of the frame is carrying loads. Traditionally couch frames are made from solid wood, which is most commonly used in higher market segments. More economic alternatives are particleboard, medium density fiberboard, pressed wood or wood contaminated with glue. Manufacturers such as Gelderland use solid beech wood and aluminium for their frames (6400 bank | Gelderland Design, n.d.), and manufacturers like Dutch Quality Group use a combination of plywood, beech wood parts and MDF (Design on Stock, n.d.) (see *Figure 2 and Figure 3*). Lower market segments use lower quality wood.

2.2.2 The suspension system

The metal nosag springs make sure the seat does not sag. The steel is electrically hardened and on average 3.7 mm thick. Every 8 – 10 cm a spring is placed, attached in a plastic or metal spring clip (MeubelVisie, 2018) (see *Figure 4*).

2.2.3 The foam layer

The main source of comfort in a couch is the foam attached underneath the upholstery (see *Figure 6*). There are different types of foam ranging from low density to high density; polyurethane foam (density 19 kg/m³, lifespan 1-2 years), conventional foam, high-density

foam, high-resilience foam and rebond foam. Each foam density fulfills a different function in the couch, so sitting foam and backrest foam differ in density. Foam characteristics are density and ILD. The higher the foam density, the higher the quality and durability of the foam. Indentation load deflection (ILD) measures a foam's firmness (SleepOnLatex, n.d.).

High-market segment manufacturers use High-Resilience (HR) foam, with a density of 43 kg/m³ and an average lifespan of 12 years (FoamOnline, 2024). Firmer foam types such as rebond foam are used in different areas of the couch that endure daily high usage or impact such as the corners or the front of the frame. Rebond foam is constructed by shredding leftover foam pieces and pressing them together so they bond into one solid block. It is available in multiple densities, Dutch Quality Group uses several types ranging from 140-160 kg/m³.

The foam is glued on the wooden frame, and afterwards other foam layers are glued on top of the foam (see *Figure 7*).

Around the foam a layer of Dacron is glued and wrapped. Dacron is a polyester fiber used as a filling material, which is used as an intermediate layer between the upholstery and the foam filling (BLADI Meubelstoffen, 2025). It provides the soft, fluffy feel of the couch surface (see *Figure 8*).

2.2.4 The upholstery layer

For this project, leather upholstery is deliberately excluded, despite its long lifespan, since sales of leather couches are decreasing.

All couches are finished with a fabric cover, which is cut, overlapped and stitched. For high-market segment couches, high-quality fabrics are used, such as De Ploeg, Kvadrat and Gabriel.

Fabric lifespan depends on:

The Martindale value:

Measures abrasion resistance, by rubbing sandpaper or wool over the fabric until it starts to show distress or breaks (Alice, 2026). Scores rate:

- <15,000 : decorative use
- 15,000 - 40,000 : norm for seating furniture
- 40,000 - 75,000 : fit for intensive use
- 75,000 - 100,000 : very strong fabrics

(Table du Sud, n.d.)

Pilling resistance:

Pilling refers to small fiber balls that form on the surface of the fabric. The loose fibers tangle together during normal use. There is a 1-5 grading

scale, ranging from 1 meaning severe pilling to 4-5 meaning pilling resistant material, with premium quality (Hnleading, 2026).

Lightfastness:

The amount a fabric changes in color after it has been exposed to sunlight (Darong Textile Tester, 2024).

2.2.5 The connection system

The way a couch is constructed is very dependent on the market segment it is produced for. The way the parts of a DQG couch are connected is shown in Table 1.

Barriers

Couch is built up with many permanent fastening types, mainly glue.
Underlayer fully tacked.
Main wear components: Fabric pills and breaks, foam sags.

Opportunities

Use of reversible connections instead of a lot of tacks. Examples: velcro, buttons, zippers etc.

FASTENING TYPE: EASE OF REVERSING (easy (left) to difficult (right))					
PARTS	OTHER	BOLTS	OTHER	TACKS	GLUE
Wooden frame		x	Insert nuts	x	x
Foam layers					x
Dacron layer					x
Fabric cover			Stitched		
Upholstery			Velcro, pullstrips	x	x
Nosagspring clips				x	
Nosagsprings	In Nosagspring clips				
Felt layer				x	
Attachments		x			
Underlayer				x	

Table 1: Fastening types of parts in the couch, reversible or permanent

3. HOW IS A COUCH MANUFACTURED?

Couch production follows a linear process, visualised in *Figure 9*. Individual components such as the wooden frame, foam parts and upholstery are prepared first, after which they are assembled into a finished product.

In *Table 4 in Appendix C-A* the production times are logged for an Aikon Lounge '13. The most time-consuming steps are emphasised in bold, so tacking wood, gluing the foam and upholstery take the longest.

The production data shows that several of the most time intensive steps occur in the outer layers of the couch, particularly foam glueing and upholstery. These layers are attached after the structural components of the couch have already been assembled.

Because refurbishment would require removing these layers again, the manufacturing process directly influences how easy or difficult refurbishment becomes.

To calculate production costs, the formula shown in *Appendix C-A on page 107* was used.

The next chapter analyses which materials have the highest environmental impact.

Opportunities

Approximately 60 minutes of production time can be eliminated when reusing the wooden frame. This translates to approximately €60. This gives room for refurbishment steps.



Figure 9: Manufacturing flow Dutch Quality Group (Created by the author)

4. WHAT PARTS HAVE HIGHEST ENVIRONMENTAL IMPACT?

4.1 Fast-track LCA

A fast track Life Cycle Assessment was conducted to estimate the climate impact of the Aikon Lounge '13 sofa and identify which parts contribute most to the total result. The assessment was used as a design tool, not as a complete environmental assessment. Its main purpose was to understand where the largest climate impact is located in the product, so that later design decisions could focus on the parts where replacement, reuse or refurbishment matter most.

The impact category used in this assessment is Global Warming Potential, expressed in kg CO₂ equivalent. This means that the results do not represent all environmental effects of the couch, but only its contribution to climate change. Other impact categories, such as water use, land use, toxicity, acidification, eutrophication and resource depletion, were not included. The results should therefore be read as an indicative comparison of climate impact, not as a complete LCA.

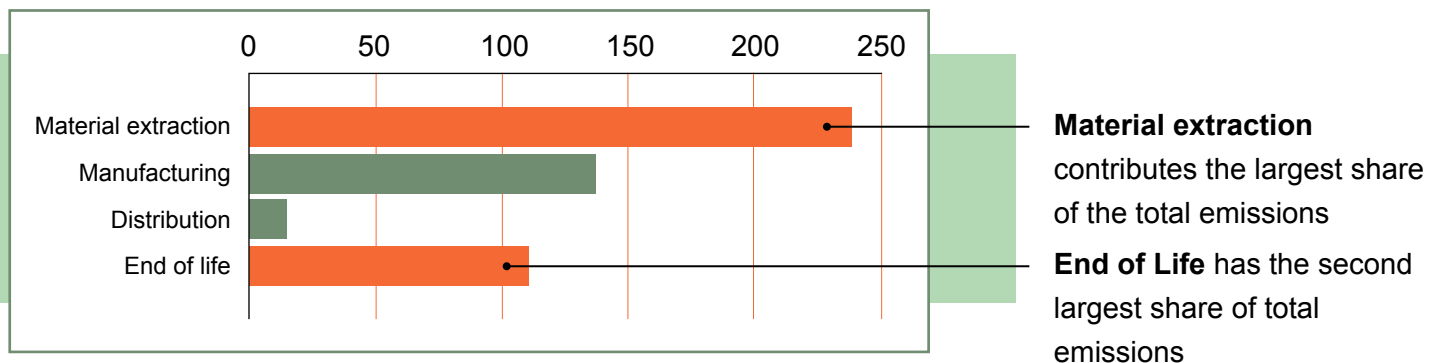


Figure 10: Global warming potential equivalent (kgCO₂-eq) by life cycle stage of Aikon Lounge '13

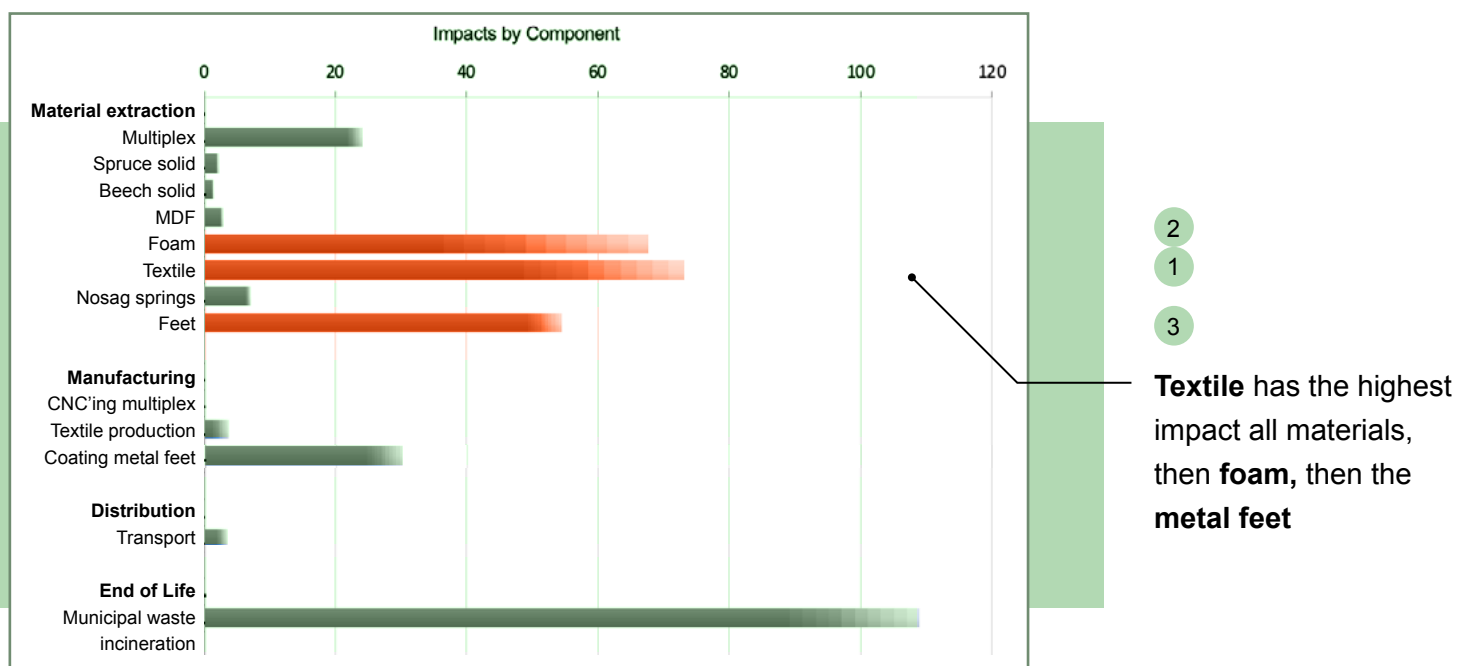


Figure 11: Global Warming Potential, kg CO₂-eq, by component of the Aikon Lounge '13

The physical reference product used in the assessment is two Aikon Lounge '13 right modules. The material masses were taken from a SolidWorks model provided by Dutch Quality Group. The assessment includes raw material production, transport of materials to the manufacturer, distribution to dealers, manufacturing and end of life treatment. The use phase was excluded because upholstered furniture has no operational emissions during use. Because this project focuses on lifetime extension, the functional unit should not only be understood as the physical couch itself, but as the seating function provided by the couch over time. For this reason, the same LCA data can later be translated into climate impact per hour of use. This makes the effect of longer product use visible.

GWP per hour of use = total GWP / expected lifetime use hours

Expected lifetime use hours = lifespan in years × 365 × assumed hours of use per day

A couch with no emissions during use can still become less impactful per hour when it stays in use for longer, because the production and end of life impacts are distributed over more use hours. The final design comparison therefore uses this logic to evaluate whether reusing the frame and selectively replacing foam can reduce the climate impact per use cycle.

Figure 10 shows the climate impact divided by life cycle stage. Material production has the largest contribution. End of life has the second largest contribution. Manufacturing, transport and distribution have a smaller contribution compared to the material related impact.

Figure 11 shows the climate impact divided by component. The results indicate that textile and foam are among the most relevant parts from a climate perspective. This is important because these parts are also located in the outer layers of

the couch and are among the first components to lose functional or aesthetic value during use.

4.2 Conclusion

The results show that textile and foam account for the largest share of the couch's environmental impact, yet they are also the first components to wear out. This creates a contradiction: early replacement increases environmental impact, but replaceability is necessary to extend the lifetime of the couch and preserve its value.

The next chapter therefore analyses which design decisions currently prevent replaceability from happening.

5. WHAT ARE PAIN POINTS OF COUCH DESIGN FOR CIRCULARITY?

Pulling upholstery over foam takes effort and time, lubricant sprayed on Dacron

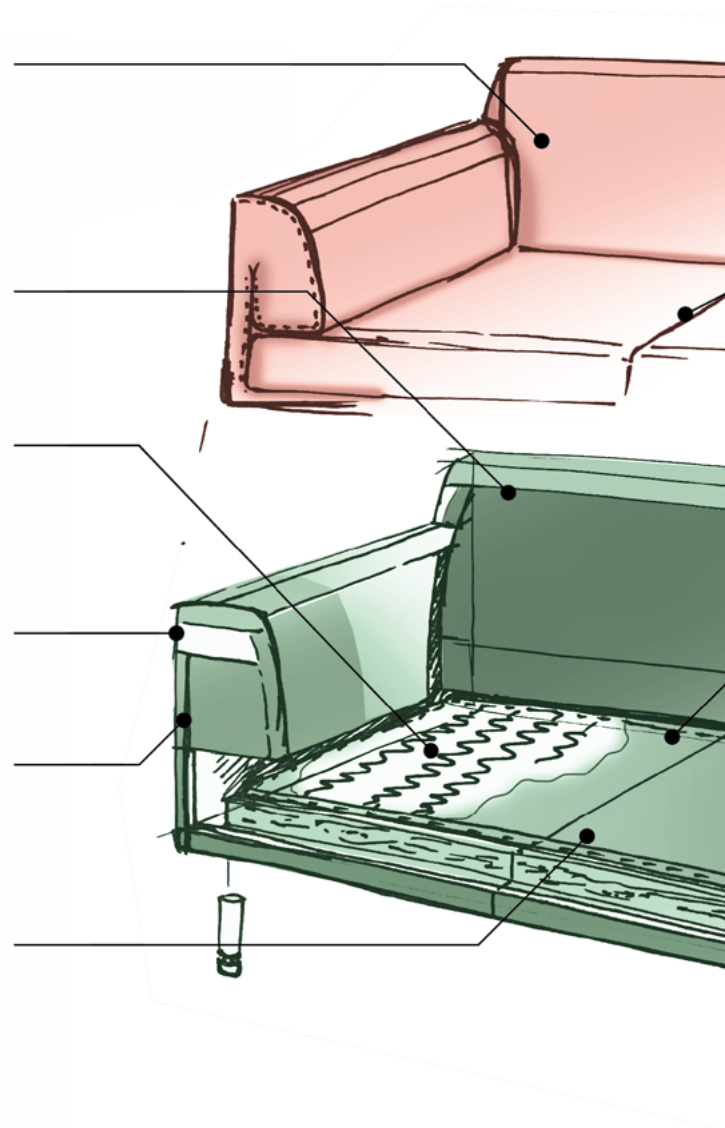
Foam is glued on wood and mdf

Nosag springs in plastic clips, plastic clips are stapled on wood

Foam is glued on a new layer of foam

Many different foam types with different densities

Felt toplayer stapled to wood



Observations from factory visits at DQG indicate that the couch design and production process are primarily optimized for manufacturing efficiency. Several of these design and production decisions directly hinder circularity. The main pain points identified in the product architecture are shown in *Figure 12*. This work was based on the findings of Intven et al. (2022), combined with additional insights from the author's own couch analysis. Three overarching themes emerge from this analysis.

1. **Material separation is complex**
2. **Materials have relatively low residual value**
3. **Use of permanent fastening methods**

Within this set of barriers, two challenges appear to have the largest influence on the feasibility of refurbishment. Both challenges are based on production time and fastening type, which are shown in *Table 1 on page 17* and *Table 4 in Appendix C-A*.

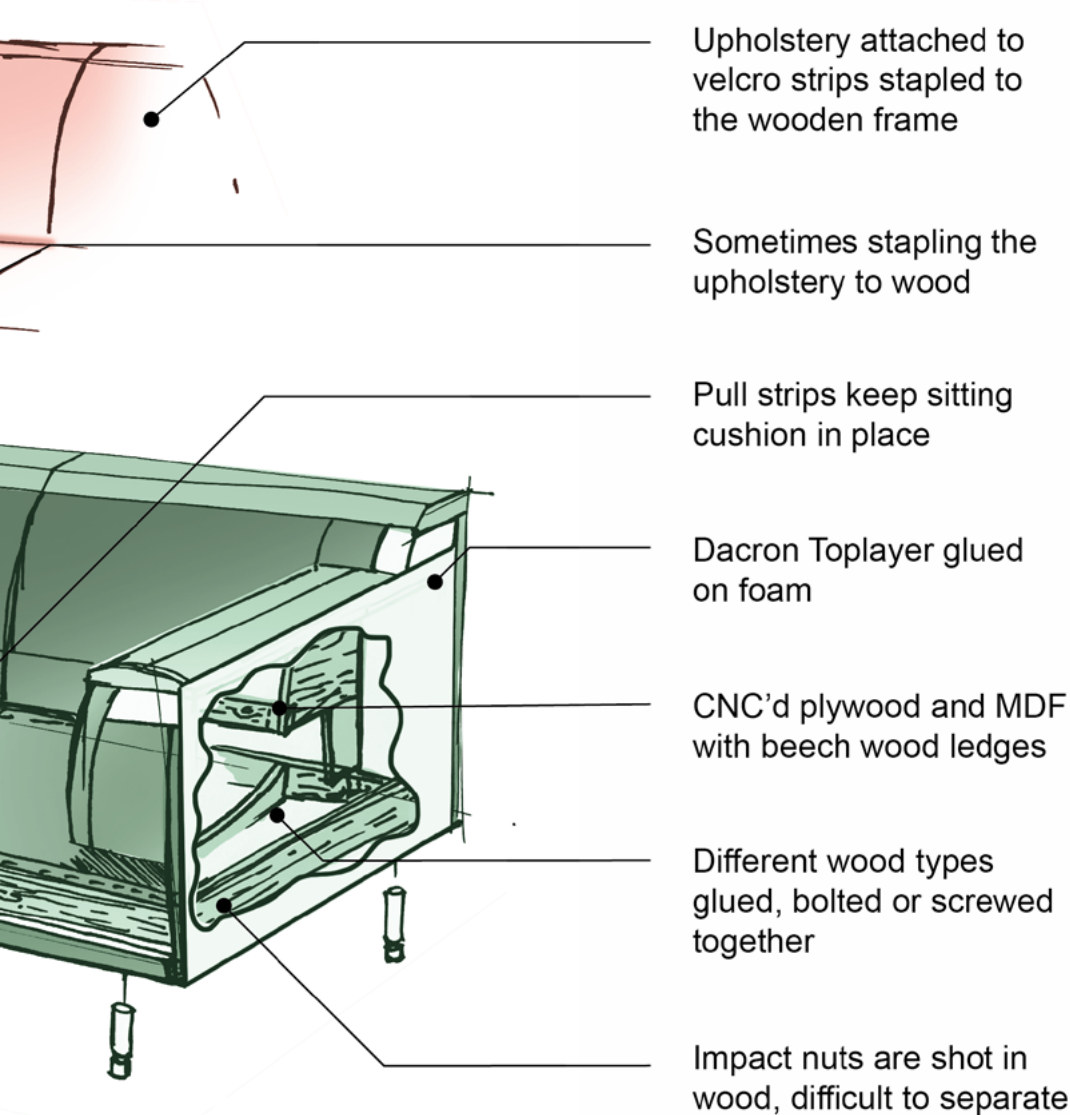


Figure 12: Exploded view of a Dura couch with pain points for circularity (Brand: Eyye). (Created by the author).

The challenges are:

1. The **upholstery**, with intensive labor during the upholstery process
2. The **foam layer**, which is glued directly onto the wooden frame and therefore requires effort and time to remove during disassembly.

Both are located in the outer layers of the couch, which are also the components that wear out first during use.

Opportunities

The fabric and the foam make up approximately 25% of the weight of the couch (see Figure 5 on page 15). If refurbishing enables reuse of the wooden frame, the velcro, felt layer, the nosag springs and the underlayer, we could reuse approximately 75% of the weight of the couch.

6. WHAT DO OTHER STAKEHOLDERS THINK?

6.1 Method

Eight semi-structured interviews were conducted with stakeholders across the Dutch furniture sector to understand how sustainability and circularity are perceived (see Table 2).

The interviews aimed to capture perspectives from multiple positions in the system, including manufacturers, retailers, refurbishment companies, and circular furniture initiatives.

Questions were adapted per stakeholder type but generally addressed three themes:

- 1. Product design and lifespan
- 2. Logistics and system organization
- 3. Economic and market conditions for sustainable furniture initiatives.

Interview data was documented through written notes and recordings where possible. The interviews were subsequently analysed using thematic analysis, in which recurring patterns and perspectives were identified across the different stakeholders (Ahmed et al., 2025).

6.2 Results

The thematic analysis identified six recurring themes regarding sustainability and circularity in the furniture sector shown in Figure 13. Quotes were added to provide context.

6.3 Key insight

Together these findings indicate that extending the lifespan of couches requires interventions at multiple levels of the system. Product design can enable repair and refurbishment, but logistical infrastructure, economic incentives, and collaboration between stakeholders are equally important for circular systems to function.

Themes 2, 5, and 6 are the most important, because they directly relate to designing couches for easier refurbishment, prioritising reuse over recycling, and ensuring that circularity is translated into practical user and business value.

ORGANISATION	TYPE OF STAKEHOLDER	SPOKESPERSON
IKEA	Global furniture producer	(1) Karla van Ingen, (2) Gilbert de Jong
Gelderland	Dutch furniture manufacturer	Remco van der Voort
Kairos	Circular furniture manufacturer	Eelco Schouten
Spinde Next	Furniture retailer	Speaker 1 and 2
Nomot	Furniture repair	Jeroen Gerritsen
Demontagehal Almere	Municipal disassembly facility	Femke Mostert
Lande Family	Dutch furniture manufacturer	Charlotte van der Lande
Het Anker	Furniture manufacturer	Ron Gubbels

Table 2: List of organisations and spokespersons interviewed

1 LOGISTICS AND SCALABILITY RESTRICT CIRCULAR SYSTEMS

Transport costs, reverse logistics and the difficulty of batching products were frequently mentioned barriers.

“Transport is een heel groot probleem” - IKEA1

“De binnensteden worden steeds meer autoluw” - SPN1

2 PRODUCT DESIGN DETERMINES LIFESPAN AND REFURBISHABILITY

Design decisions strongly influence whether furniture can realistically be repaired or refurbished. Examples include reducing glue connections, using removable upholstery, and designing modular components that can be replaced individually.

“Gebruik geen lijm, maar gebruik een rits, en gebruik geen tacks maar gebruik een stukje klittenband” - LAN

“Door de stoffeerstrip van Gelderland is demontage 20x sneller klaar” - NOM

3 CIRCULARITY REQUIRES AN ECOSYSTEM OF PARTNERS

Circular systems require collaboration between multiple actors. Manufacturers, retailers, refurbishment companies, recyclers, and municipalities all play a role in enabling product lifespan extension.

“Dan moet er eigenlijk een hele keten opgezet worden” - IKEA1

4 EXISTING MARKET STRUCTURES MAKE CIRCULAR BUSINESS MODELS DIFFICULT

With the furniture sector currently structured around linear product sales, circular business models face structural barriers. Strategies such as refurbishment will only be adopted when they are economically viable.

“Is een euro in de productie duurder, is het een paar euro duurder in de showroom” - KAI

5 REUSE IS PRIORITIZED OVER RECYCLING

Stakeholders highlighted that recycling often results in loss of material value, while reuse retains the highest value of the product.

“Je moet alles doen om te voorkomen dat het recylen wordt” - IKEA2

6 CIRCULARITY DOES NOT SELL, USER VALUE DOES

Consumers primarily respond to direct benefits such as price, comfort, and convenience, with circularity as an underlying system quality rather than a primary marketing message.

“Voor klanten is circularity en sustainability niet het argument” - IKEA1

“Praktische punten ... waar je als consument direct zelf wat aan hebt” - KAI

Figure 13: Six themes thematic analysis

7. BSR COLOUR MODEL DQG

To better understand the target customers for DQG's couches, a meeting was held with DQG's sales manager, Claire Derison. During this meeting, she explained the company's colour model, which is used to position the brands and understand the values and motivations of different consumer groups. The full handout is displayed in *Appendix C-B on page 108*.

DQG uses its Brand Strategy Research (BSR) colour model to position its brands and understand consumer behaviour (see *Figure 14*). The model divides consumers into lifestyle groups based on values and motivations. Within this model, DQG mainly targets the blue and red segments, which are associated with status, quality, individuality, innovation and performance. Green and yellow consumers are more strongly driven by social values, harmony and sustainability related motivations.

This model also helps explain one of the key findings from the thematic analysis in Chapter 6, where multiple stakeholders stated that circularity itself is often not the main purchasing argument for consumers. Instead, customers respond more strongly to direct user benefits such as comfort, convenience, quality and status, which align more closely with DQG's blue and red target groups.

Therefore, circular interventions should be communicated through the added value they create for the user, such as higher quality, easier maintenance, longer product lifespan, flexibility or premium service.

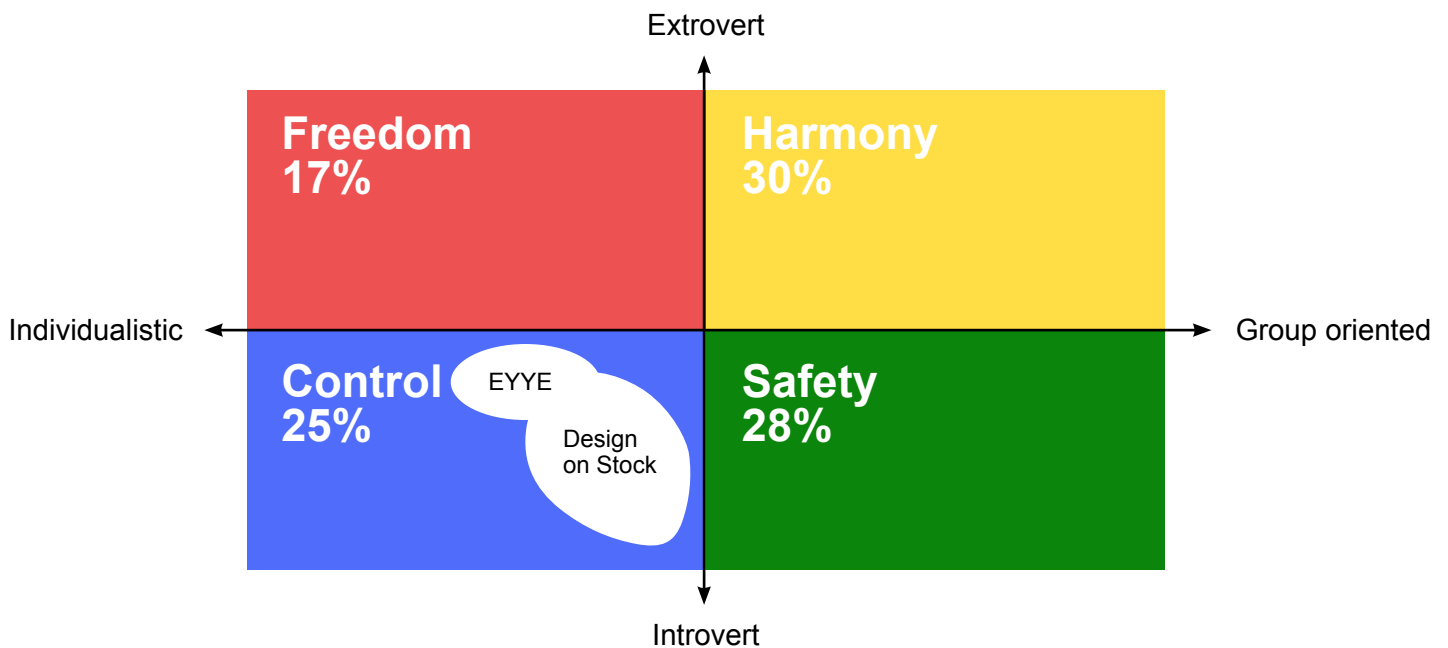


Figure 14: Positioning of DQG brands within the BSR colour model.



Photograph taken during the Gelderland visit, where I tested installing the upholstery strip in the couch frame.

8. SYSTEM MAP OF THE SUPPLY CHAIN

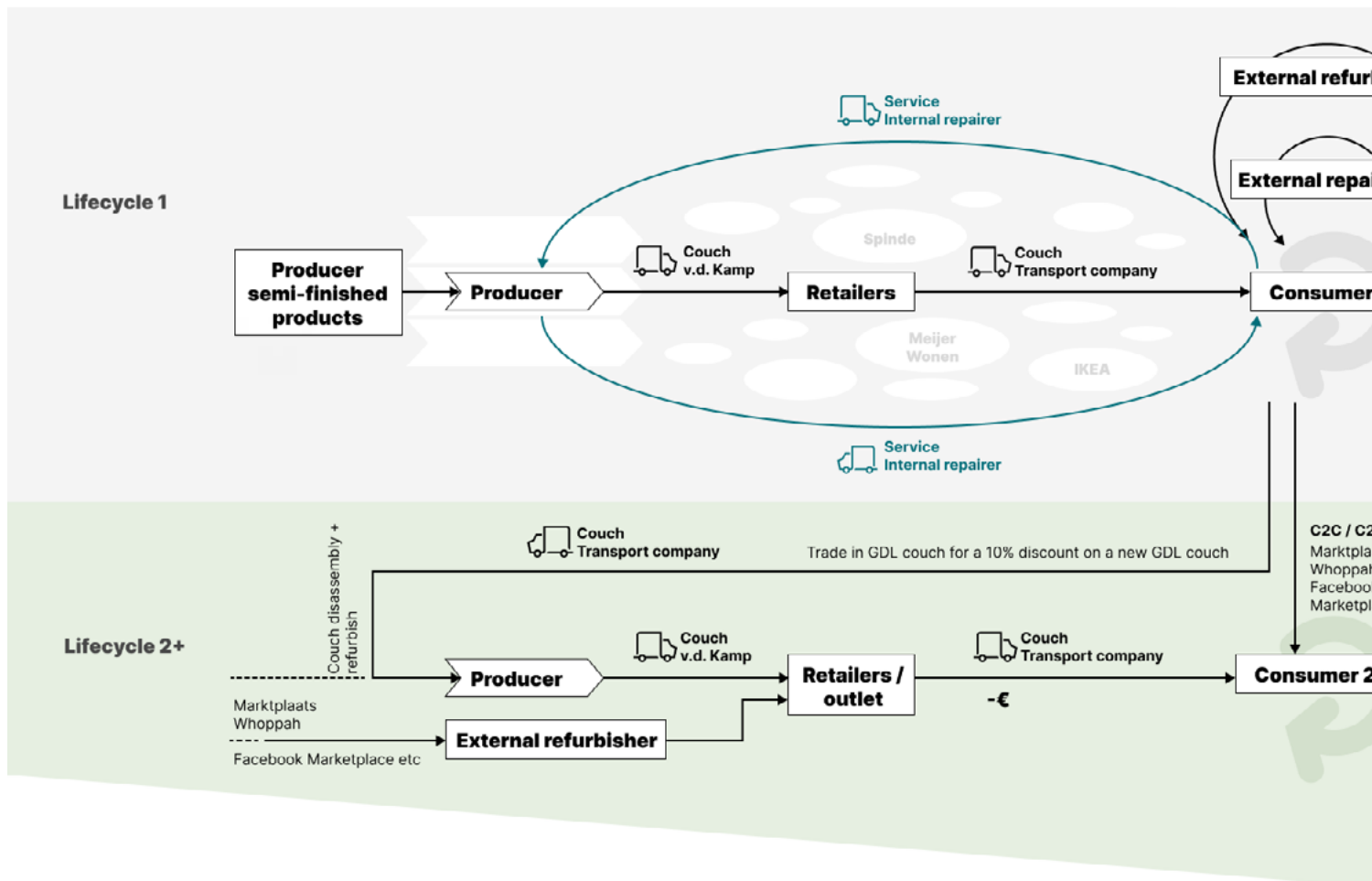


Figure 15: System map couch value chain

8.1 System map of supply chain

To understand where intervention is most needed, the current couch value chain was mapped as a system. The map in *Figure 15* gives a qualitative overview of the main actors and routes through which couches move after production. The second map in *Figure 16* on page 30 translates this structure into indicative material flows in kilotons. The third map in *Figure 17* on page 32 then explores how this system could shift over the next five years if refurbishment and disassembly activities increase.

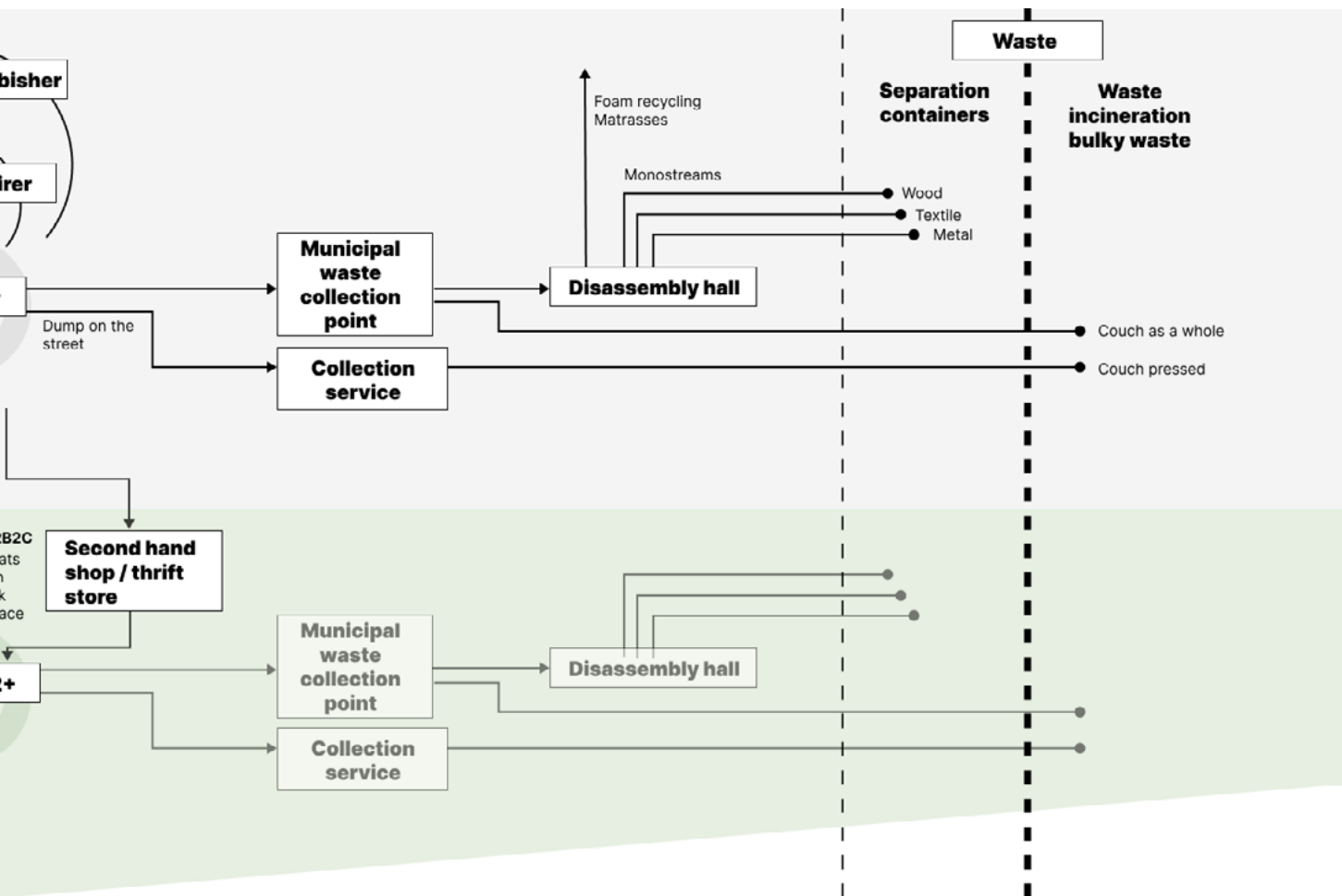
8.1.1 From producer to consumer

Figure 15 presents the current supply chain of couches in the Netherlands. At the start of the chain manufacturers and suppliers of semi-finished products operate. From there, couches move to dealers and then to consumers. This is

the dominant first lifecycle. In the current system, the main value creation is concentrated around the sale of a new product, while the period after purchase is only lightly supported through maintenance, repair, or take-back.

8.1.2 Parallel routes to Lifecycle 2+

The map also shows that this system is not fully linear. Around the main flow, several alternative routes already exist. Some consumers resell their couch through consumer-to-consumer platforms such as Marktplaats, Whoppah, or Facebook Marketplace. Others bring their furniture to second-hand shops. In addition, external repairers and refurbishers already operate in the system. These actors range from independent upholsterers to specialised companies carrying out repairs for insurance cases, such as Nomot, or full reupholstery for private customers. These actors



create a second or third life for some couches, but they remain marginal to the dominant market structure.

8.1.3 From consumer to waste

Once a couch leaves use and is no longer resold, it generally enters the municipal waste system. In the current situation, this means that many couches are brought to the milieustraat or collected as residual waste by municipal pickup services. From there, most end up in sorting and incineration. This route is still the default end-of-life pathway for large volumes of upholstered furniture.

8.1.4 Disassembly hall

Since 2024, a new actor has entered this chain: the disassembly hall. Disassembly halls have opened in locations including Almere and Breda, both connected to municipal waste collection sites

(Mettler, 2024; Flevolandse Circulaire Innovatie Top, 2026). At these facilities, furniture is manually taken apart in social employment settings and separated into cleaner material streams. Materials such as wood, metal, leather, and some foam fractions can then be redirected to recycling or reuse applications. These facilities reveal the limitations of the current product architecture. If foam is contaminated, mouldy, or laminated with glued textile or plastic layers, it often still ends up as residual waste. The same applies to large parts of the textile fraction, for which large-scale recovery routes are still limited.

Barriers

Mixed material contamination reduces recycling quality, dealer network blocks washable covers because own laundry service.

Opportunities

Existing repair/refurbishment actors are already active (Gelderland), easier disassembly improves value retention

SYSTEM MAP OF THE SUPPLY CHAIN

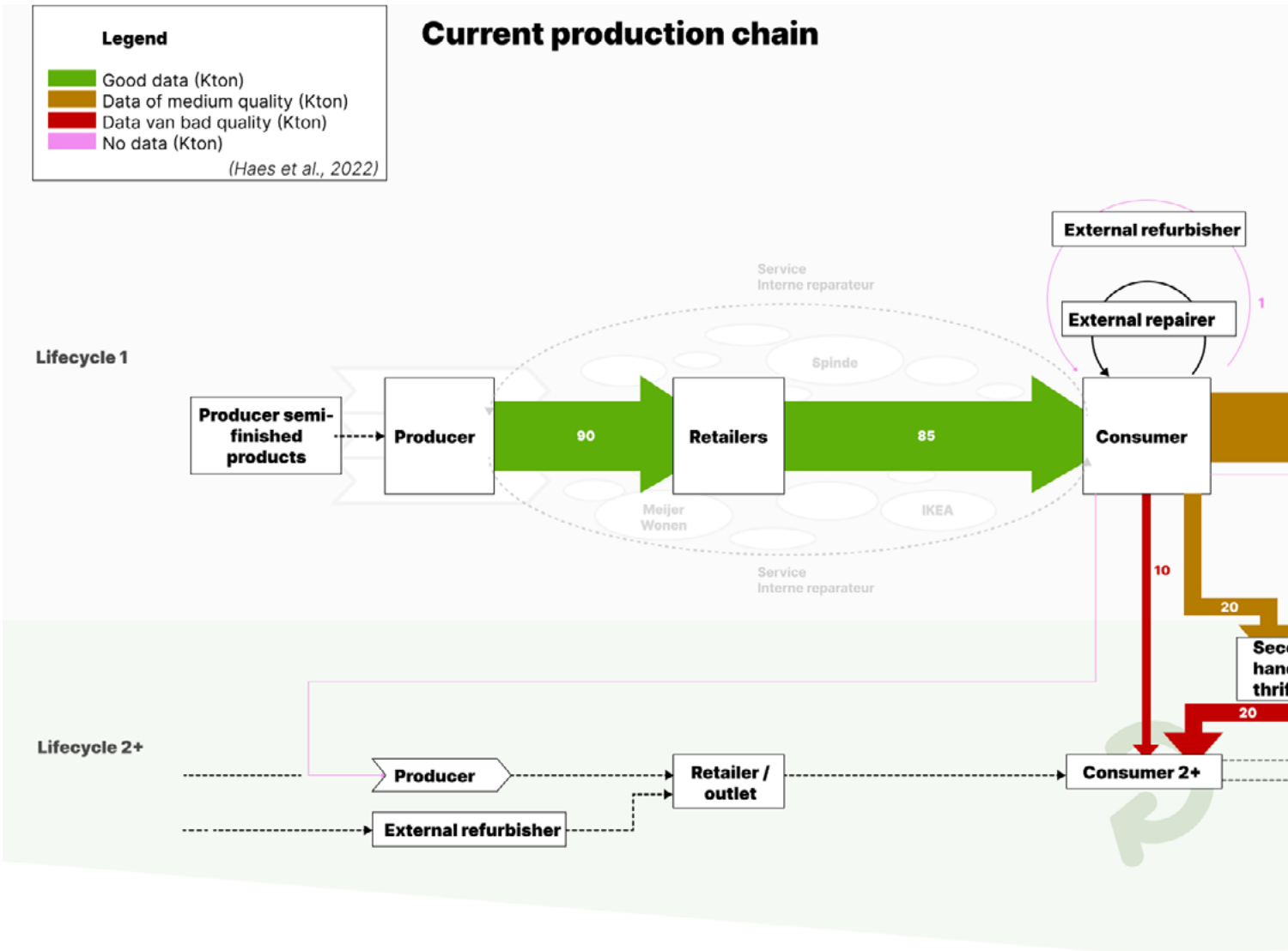


Figure 16: Translation of system map to one with material flows

8.2 System map with material flows

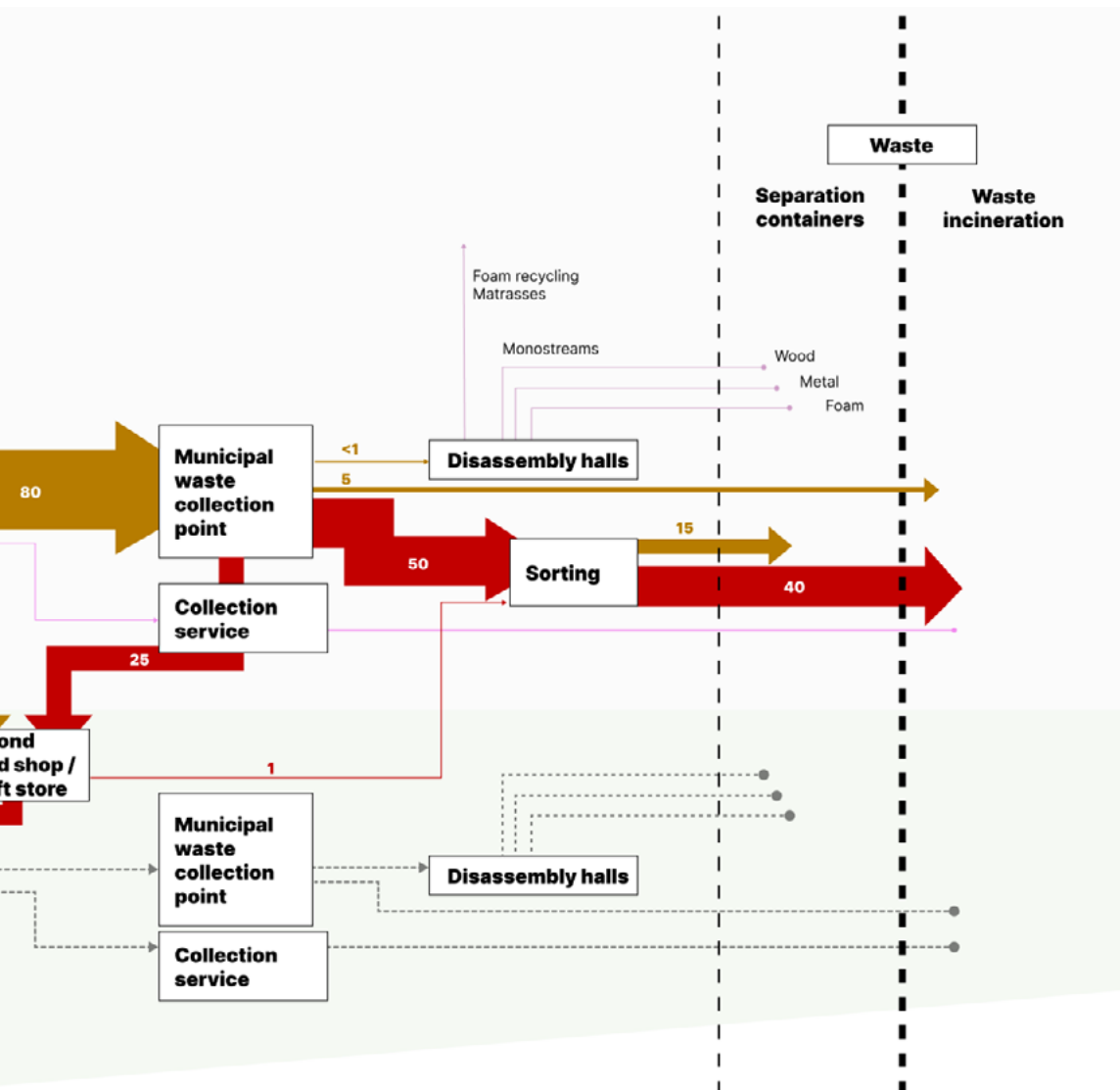
Figure 16 builds on the map in Figure 15 by adding estimated flows in kilotons, based on research from Haes et al. (2022). This shows where the largest volumes move through the system and where the biggest losses occur. The purpose of this map is not to present exact national statistics for every route, but to show the order of magnitude and the relative balance between the main flows. As shown in the figure, not all flows are fully closed; according to Haes et al. (2022), data is still missing for parts of the recycling and craft center flows, and there is also an unexplained gap of around 30 kton between purchased and discarded furniture, which indicates that these flows should be interpreted with caution and require further investigation.

8.2.1 Flows leaving Lifecycle 1

The map indicates that the largest share of couches, 90 ktons, moves through the conventional first lifecycle, from manufacturer to dealer to consumer. After use, a substantial volume, 50 ktons, leaves the value chain through municipal collection and residual waste processing. A smaller share, 30 ktons, moves into second hand routes or remains in use through informal resale. An even smaller share enters repair, refurbishment, or material recovery.

8.2.2 Challenges in circular routes

What becomes visible in this translated map is that the problem is not the absence of alternative pathways, but their scale. Second hand routes exist, but they capture only a limited part of the



Barriers

- Scale of second hand routes is limited
- High value loss after use phase
- Contaminated material streams, or streams without purchaser

Opportunities

- High residual couch value
- Existing refurbish ecosystem
- Faster refurbishment
- increases feasibility

total flow. Repair and refurbishment exist, but they are labour intensive and not yet organised at scale. Disassembly halls can recover material streams, but they only come into play after a product has already become waste. Additionally, the monostreams need large-scale purchasers. This means that much of the original product value is already lost by the time recovery starts.

8.2.3 Loss of value in waste and sorting

The flow map also highlights where quality is lost. When a couch is discarded through the residual waste system, the product usually becomes mixed with other waste streams. At that point, options for direct reuse or easy refurbishment decrease rapidly. Even within disassembly halls, not all material fractions can yet be recovered while

retaining high value. Clean wood and metal can often be separated effectively, but contaminated foam and textile remain a problem. This confirms that recycling alone cannot solve this challenge. Once the product reaches the waste phase, a large part of the embedded value has already been destroyed.

8.2.4 Value retention hierarchy

For this reason, the map supports the hierarchy that also emerged from the interviews: keeping couches in use for longer is preferable to recovering them only after disposal. Maintenance, repair, cleaning, resale, and refurbishment all preserve more value than material separation at end of life.

SYSTEM MAP OF THE SUPPLY CHAIN

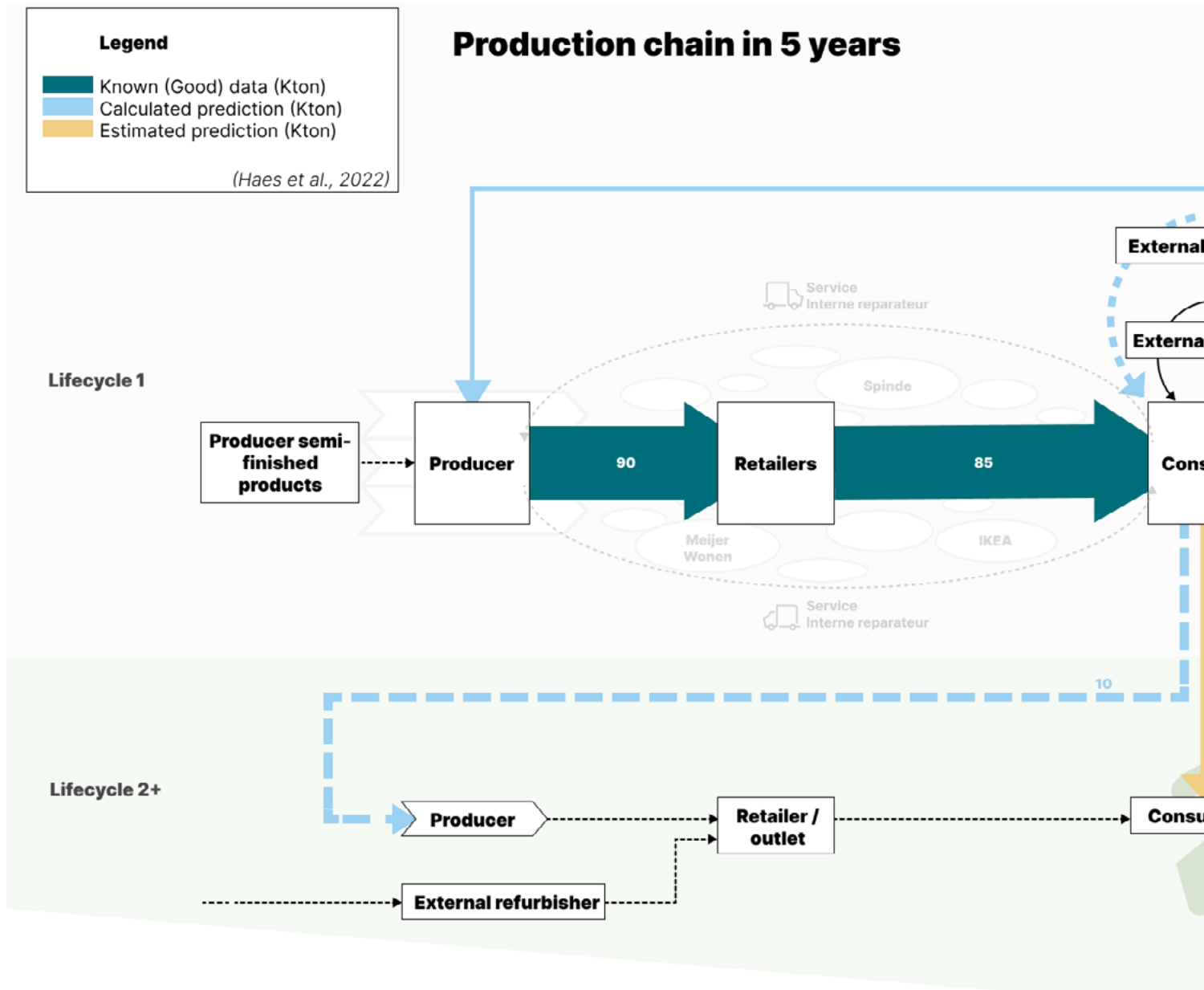


Figure 17: System map of possible future configuration in 5 years

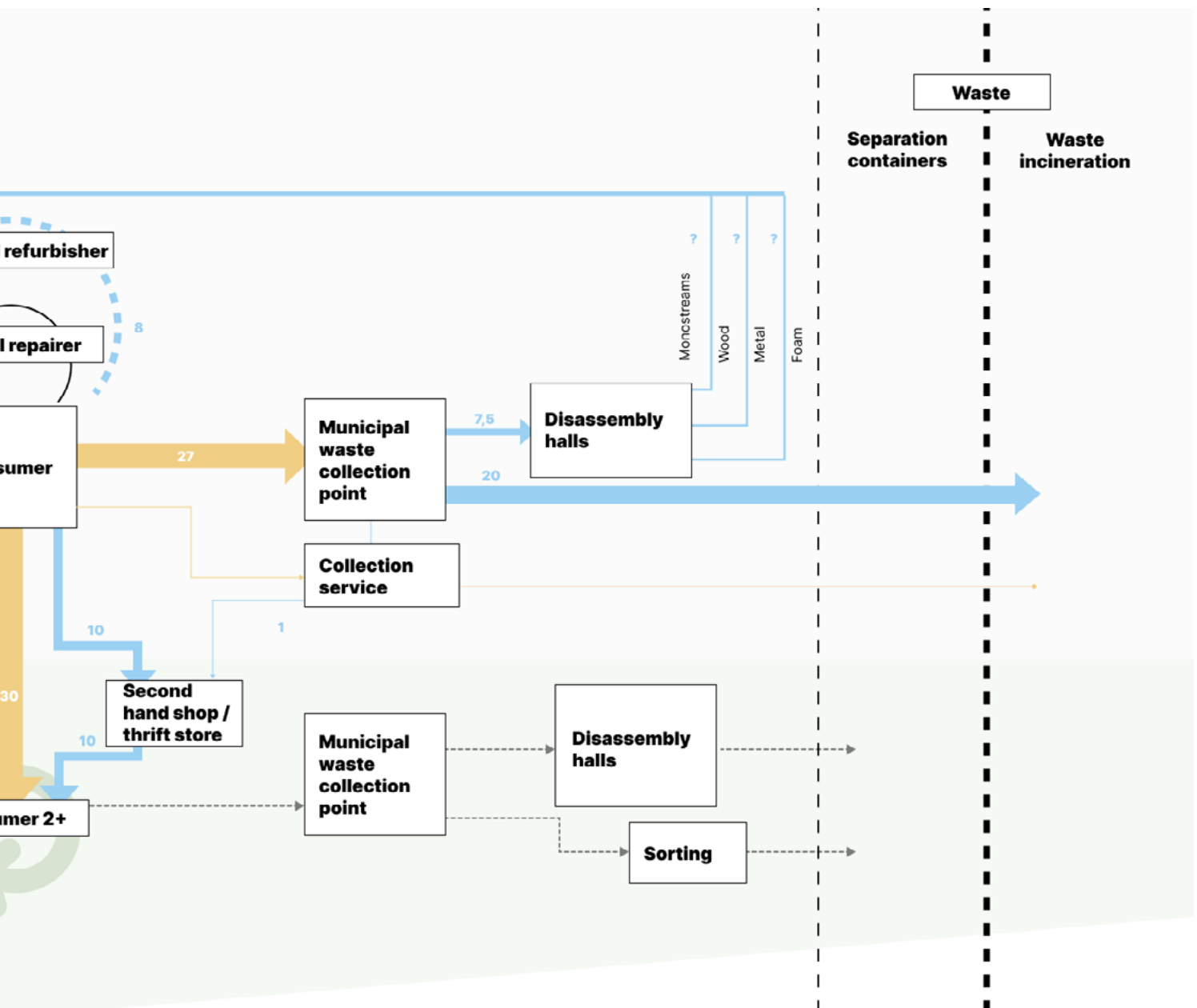
8.3 A possible future configuration in 5 years

Figure 17 presents a future scenario for the system five years from now. This map does not predict what will happen, but explores what the chain could look like if circular routes are strengthened and scaled. The values shown are therefore indicative estimates based on current data, case studies, and explicit assumptions. The data gap from Figure 16 was not corrected for, meaning the projected flows are based on the known streams only.

8.3.1 More refurbishment and second hand use

Three changes are explored in this future configuration.

- First, producers start or increase refurbishing in their factories, which could also accelerate refurbishing at external upholsterers (dashed lines).
- Second, when value is retained through refurbishing practices, direct resale to consumers is also estimated to increase, since the couch's value is recovered. Therefore buying couches second hand (from Marktplaats) will also be of higher value to the new user.
- Third, more discarded couches are processed through disassembly halls, increasing the proportion of separated material streams and reducing direct incineration.



8.3.2 Producer led and external refurbishment

Based on the number of Dutch furniture producers with a local factory, this was calculated to become 10 kton. This is only possible when refurbishing is simplified and accelerated. Once this happens, the volume of couch refurbishment is estimated to also increase at external refurbishers, to about 8 ktons.

8.3.3 Limits of producer led refurbishment

An important insight from this map is that even if all Dutch producers with local manufacturing start refurbishing their own couches, they still address only a relatively small part of the overall problem. A large share of furniture sold in the Netherlands is imported, which means that producer led

refurbishment alone cannot transform the whole system.

8.3.4 Capacity of disassembly halls

To indicate the possible role of disassembly halls in the future system, an estimated annual input capacity was calculated based on available operational data. In Breda, one employee processes roughly 45 kg of furniture per hour. Assuming an average of eight full time employees per hall, 260 working days per year, and ten active halls in the Netherlands within five years, this results in an estimated input flow of approximately 7.5 kton of furniture entering disassembly halls annually.

SYSTEM MAP OF THE SUPPLY CHAIN

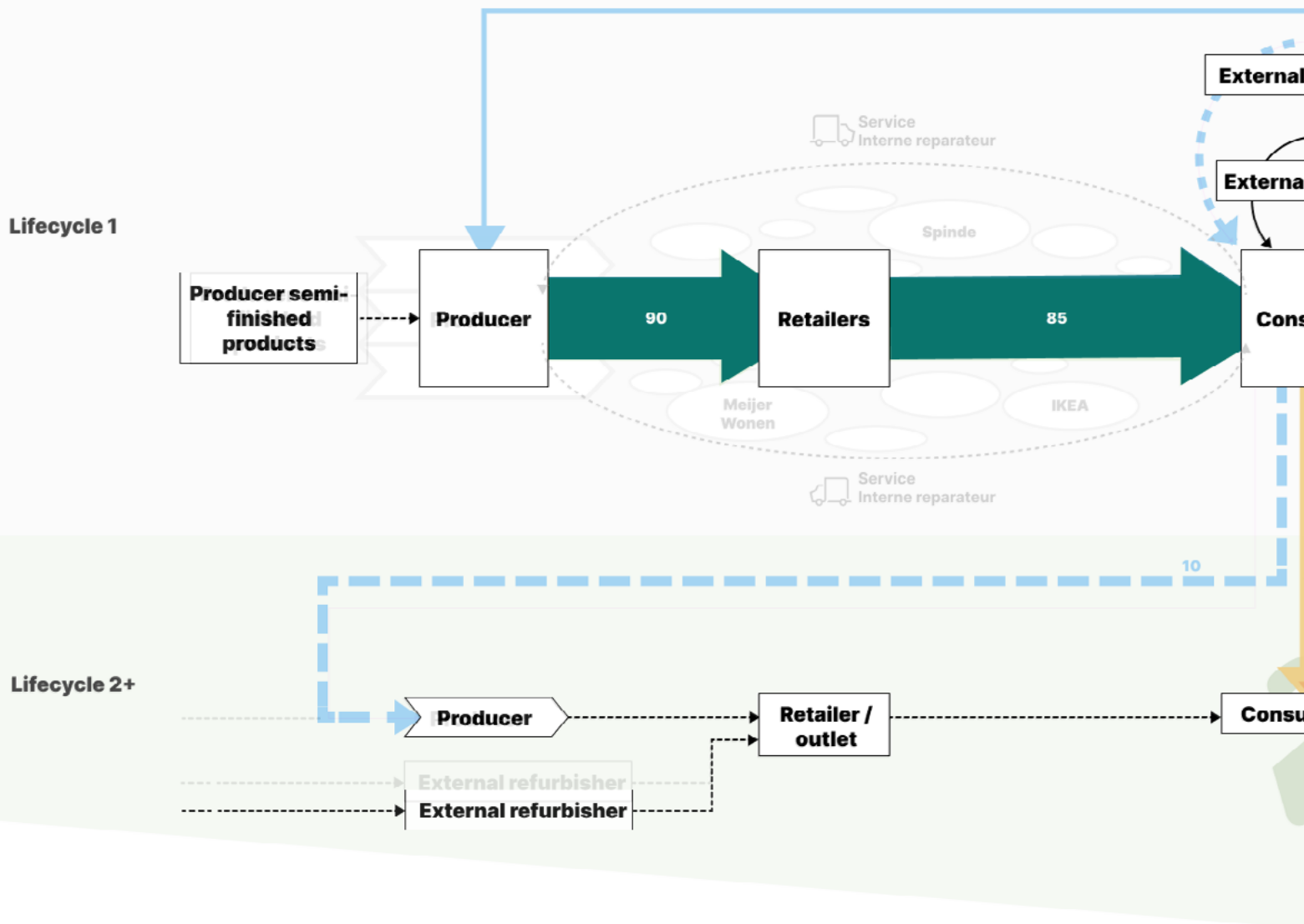
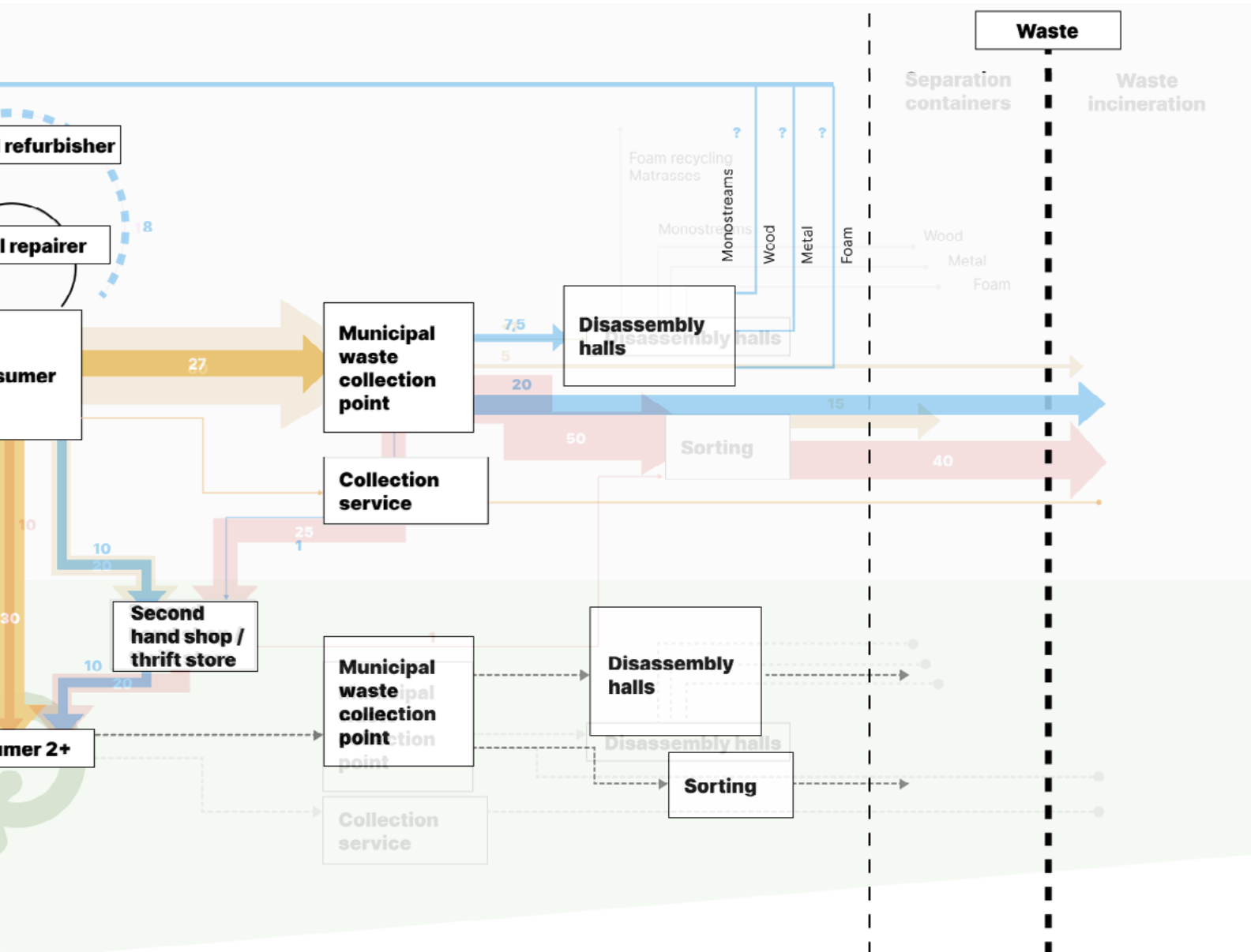


Figure 18: Overlay of both system maps

Figure 18 shows the current system map and the system map in 5 years overlapping.

The overlap immediately shows that the dominant linear flow remains, while additional routes for refurbishment, resale and disassembly begin to grow. The main opportunity is therefore to redirect couches earlier, before they enter the waste system and lose most of their product value.



However, *Figure 17 on page 32* should be read with caution. It does not mean that disassembly halls are the solution, nor does it show how much of this input will actually leave the halls as usable mono streams. At this stage, it is still unclear what share can be recovered at high value. In addition, the business case of disassembly halls is not yet self supporting. Current research from ReUse Alliance therefore focuses on improving this system through producer responsibility, for example by having producers contribute to the return and processing of parts, products, or materials, and through UPV based compensation for sorting and disassembly work. If these conditions improve, more furniture could potentially be diverted away from incineration.

8.3.5 Role of ReUse Alliance in the future system

Within this future system, ReUse Alliance mainly operates in the part of the chain after the consumer. Their role is to help organise the return chain between discarded couches and the actors that can sort, separate, refurbish, or process them further. The Bin (2025) emphasises collaboration with retailers, inkooporganisaties, milieustraten, demontagehallen, and municipal waste organisations as the natural links between consumers and producers. In that sense, ReUse Alliance is working on the system conditions needed to recover couches once they are discarded.

8.3.6 Role of design in the future system

At the same time, the future map shows where design can make a difference. If couches are easier to clean, repair, refurbish, and disassemble, more products can stay in the value chain through higher value routes. This reduces pressure on waste systems and increases the feasibility of refurbishment and reuse. In that sense, product design does not solve logistics and market barriers on its own, but it can enable a much larger part of

the system to function more circularly.

8.3.7 Conclusion

Enabling producer led refurbishment is important because it addresses the system earlier, before couches lose value in waste streams. Once a couch reaches the municipal waste collection point or disassembly hall, much of its product value has already been reduced to material value. By contrast, refurbishment at the producer keeps the couch at a higher value level for longer, makes resale more realistic, and creates a stronger basis for later repair, second hand use, or eventual material recovery. It forms the core aim of this graduation project: not to redesign the whole return system, but to make couches easier and faster to refurbish so that producer take back becomes more feasible in the first place.

Barriers

- Refurbishment remains partial solution
- Imported furniture limits producer control
- Residual waste streams still exist
- Logistics remain challenging

Opportunities

- Higher value retention
- Feasible producer take-back
- Increased resale potential
- Easier refurbishment supports scaling
- Longer use before material recovery

9. EXTENDED PRODUCER RESPONSIBILITY (EPR)

Besides environmental concerns, new policy developments are expected to make circular furniture design more important in the coming years. In the Netherlands, extended producer responsibility (the official Dutch term is “Uitgebreide Producentenverantwoordelijkheid” or “UPV”) is already applied in several sectors, including batteries, electronics, packaging materials and textiles (see *Figure 19*). The government is currently exploring an Extended Producer Responsibility regulation for furniture, with the aim of introducing a legal UPV system around 2030 (Zandbergen et al., 2023). In this system, furniture producers would become responsible for the waste phase of the products they place on the market.

The proposed UPV framework focuses strongly on reuse, repair, refurbishment and recycling. The report states that future policies may include requirements related to repairability, technical lifespan and recyclability. At the same time, it explains that current furniture products are often difficult to refurbish or recycle because they are built from many permanently connected materials.

For companies such as Dutch Quality Group, this could make refurbishment more relevant from a business perspective, not only from a sustainability perspective. The report suggests that future producer fees may depend partly on how durable,

repairable and recyclable products are. This could encourage producers to develop couches that are easier to repair, refurbish and disassemble.

The report also describes logistics, storage and labour intensive processing as important barriers within current circular furniture systems. This shows why product level interventions are important. If couches become easier and faster to refurbish, circular systems also become more feasible in practice.

For The Bin, this strengthens the importance of understanding which product characteristics support reuse and refurbishment.

For Dutch Quality Group, it shows why designing couches for refurbishment could become increasingly relevant within future production and business models.

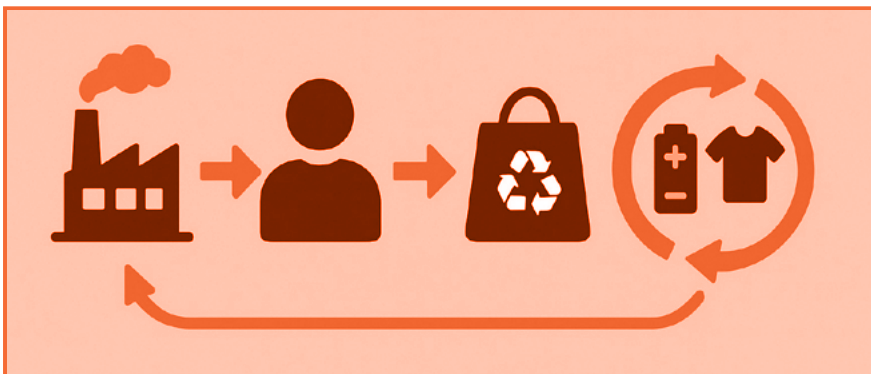


Figure 19: Extended producer responsibility visual (from <https://empact.nu/inzichten/uitgebreide-producentenverantwoordelijkheid-upv-valt-jouw-organisatie-hieronder/>)

Barriers	Opportunities
1. The couch is built up with many permanent fastening types, mainly glue. 2. The underlayer is fully tacked. 3. The main wear components are fabric and foam. Fabric pills and breaks, while foam sags. 4. Mixed material contamination reduces recycling quality. 5. Dealer networks may block washable covers because they already offer their own laundry service. 6. The scale of second hand routes is limited. 7. There is high value loss after the use phase. 8. Material streams are often contaminated, or there is no large scale purchaser for the separated streams. 9. Refurbishment remains only a partial solution. 10. Imported furniture limits producer control. 11. Residual waste streams still exist. 12. Logistics remain challenging.	1. Reversible connections can be used instead of many tacks, such as velcro, buttons and zippers. 2. Approximately 60 minutes of production time can be eliminated when reusing the wooden frame. This translates to approximately €60 and creates room for refurbishment steps. 3. Fabric and foam make up approximately 25% of the couch. If refurbishment enables reuse of the wooden frame, velcro, felt layer, nosag springs and underlayer, approximately 75% of the couch could be reused. 4. Existing repair and refurbishment actors are already active, such as Gelderland. 5. Easier disassembly improves value retention. 6. Couches still have high residual value. 7. An existing refurbishment ecosystem is already present. 8. Faster refurbishment increases feasibility. 9. Higher value retention can be achieved when couches remain in use for longer. 10. Producer take back can become more feasible. 11. Resale potential can increase. 12. Easier refurbishment supports scaling. 13. Longer use before material recovery is possible.

Figure 20: Overview barriers and opportunities from previous chapters

10. REFINED PROBLEM DEFINITION

In the current system, most couches are produced for a single linear lifecycle. Although resale, repair, refurbishment, and disassembly already exist, these routes remain small in scale and often only happen after a product has already lost much of its value. Once a couch enters the municipal waste stream, the product is no longer handled as a piece of furniture, but mainly as waste that needs to be incinerated.

For this reason, the refined problem definition shifts the focus from waste processing to product architecture¹. The context analysis shows that the wooden frame, suspension layer, and several inner components often remain usable for much longer than the outer layers. The foam and upholstery are both the parts that wear out first. They contribute the largest share of the couch's environmental footprint and are hardest to remove. Foam is glued directly onto the frame, upholstery is fixed through a mix of temporary and permanent connections, and several labour intensive steps are needed before the main wear components can be detached. This makes them the most relevant targets for redesign.

At the same time it is important to also look at how these components can be used for as long as possible, because their environmental impact is so high. Prolonged use will make the impact gradually lower. The objective will therefore not be to remove them just so we can put virgin material in. Consideration must also be given to how these materials are processed at end-of-life.

The interviews and system analysis show that circularity in furniture depends on many factors, including logistics, collaboration, and viable business models (see Figure 20). However, they also show that product design is one of the clearest points to tackle. Stakeholders repeatedly pointed to reducing glue, reducing tacks, and

introducing more removable connections as practical directions. In addition, the current production data suggests that reusing the frame could save substantial manufacturing time, meaning refurbishment does not only have environmental value, but may also create production advantages.

This leads to the following refined problem definition: **current couch designs are insufficiently configured for fast and feasible refurbishment, because the main wear components, especially foam and upholstery, are deeply integrated into the product architecture**. As a result, producers cannot easily retain product value through take-back, repair, or refurbishment.

The design opportunity therefore lies in redesigning the product in a way that makes the main wear components quicker to access, remove, replace and process, so that refurbishment becomes more realistic within existing production contexts.

What product design interventions enable producers to transition towards repairing and refurbishing their own couches?

Subquestions for the next phase will be:

1. *What are the main refurbishment barriers in the current couch design, based on hotspot mapping and disassembly mapping of a case study couch?*
2. *What product design intervention can be developed to make the removal and replacement of key wear components faster and easier?*
3. *How does the proposed intervention affect the time and feasibility of refurbishment compared to the current couch design?*

¹ For this overview, ChatGPT Plus was used to list all insights from the previous chapters and generate an outline for the refined problem definition chapter.

11. HOW DIFFICULT IS IT TO DISASSEMBLE A DQG COUCH?

To understand the time and difficulty of disassembling a DQG couch, the couch was disassembled using hotspot mapping and disassembly mapping. For this experiment the definition of disassembly is defined.

disassembly

"the action of taking something to pieces"

(Oxford Languages, n.d.)

For refurbishment it is important to disassemble the couch until the main wear components are detached, in this case, the foam and the upholstery. Therefore these maps will be logged until all is left is a wooden frame, which includes the wooden beams, nosag springs, felt layer and underlayer.

The different disassembly steps were logged and recorded using a GoPro.

11.1 Hotspot mapping

With hotspotmapping there are five indicators to assess the product architecture on (Flipsen et al., n.d.). These are:

1. Time
2. Accessibility
3. Priority parts
4. Economic value
5. Environmental impact

In *Appendix P-E on page 130* the Hotspot Map of the couch is shown. 19 operations were needed to disassemble the frame and the seat cushion until all materials were separated. 5 tools were needed to perform the disassembly, see *Figure 21*. The total disassembly took **1778 seconds**, which is approximately **30 minutes**.

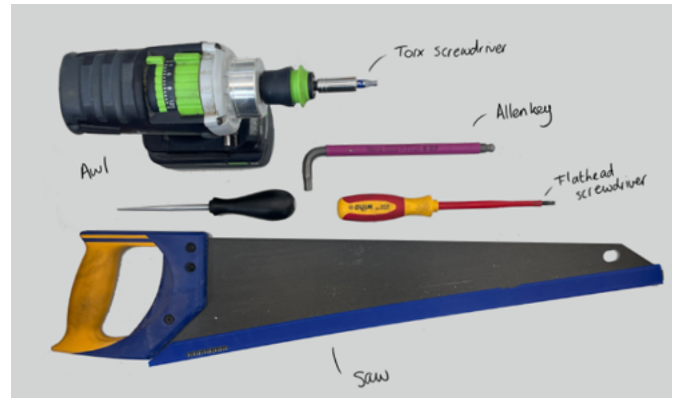


Figure 21: Tools needed for disassembly

The steps that took the longest were sawing the foam loose from the wooden frame, which took in total **587 seconds**, which is **9 minutes and 47 seconds**.

However, removing the fabric from the frame took even longer, because other tasks needed to be performed first. First the underlayer needed to be unzipped (step 4) and then the strips that held the cushion in place needed to be removed (steps 5 and 6). The fabric cover is attached with Velcro and staples in the corners, so that needed to be pulled free and removed (steps 7 and 8). Then the fabric could be stripped from the main frame, but it was still attached to a cover around the seat cushion. Steps 10 to 13 enabled the removal of that cover, with steps like staples removal and undoing zippers. In total the fabric cover removal took **825 seconds**, which is **13 minutes and 45 seconds**. *Figure 22* shows the ratio of the different disassembly steps in a pie chart.

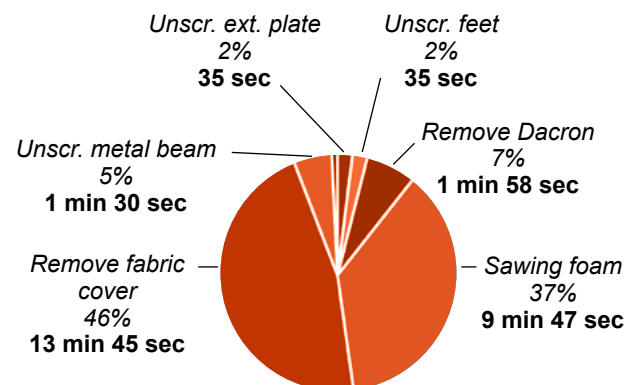


Figure 22: Pie chart of disassembly times ratio



Figure 23: Prying staples loose from fabric cover with awl

The most difficult step in terms of force, which is flagged in the **Activity** column (see Appendix P-E on page 130), were removing the staples from the wood with an awl in steps 6 and 7 (see Figure 23).

Priority parts are the fabric and the foam at the top, back and seat cushion (step 13 and 17-19), since they are made from synthetic textiles and foam. The most critical part is the fabric, since it has a red flag in the priority part and environmental column, and it takes the longest to disassemble. Furthermore, the foam seat cushion and the backrest foam have three red flags, which also make them critical parts. The armrest foam has two red flags and one orange, but it falls in the same category as the backrest foam, which also makes it a critical part.

Insights:

During disassembly, several practical issues became visible. There were no cues on which steps should be done in which order, so the sequence had to be figured out by trial and error. Some connections were also unclear in function, for example the seat cushion was fixed with one white strip stapled into the corner, and it was not immediately obvious whether this strip had to be removed to release the cushion. Staples in textile were relatively easy to remove with a flathead



Figure 24: The three critical parts together (seat cushion 1 and 2 and the fabric cover)

screwdriver, while staples in wood were much harder to remove and required an awl. Even then, staples often remained half stuck in the wood, making them difficult and painful to pull out by hand. A plier could have been used to do this. The fabric was also damaged when the awl was inserted under the staple. Dacron layers could be pulled off the foam quite easily. In hindsight, the harder blue rebond foam parts could have been left in place during the next attempt. Small foam particles also fell into the wooden structure of the couch during removal. This is undesired when refurbishing the couch. When cutting along the MDF panels, the saw damaged the boards. In the cushion upholstery, there was also a row of tacks in a place where this did not seem necessary, because if there had been a zipper or velcro, the cover could have been removed much faster.

11.2 Disassembly mapping

With information from the Hotspot Map, a disassembly map was drawn up (see *Figure 26*). From this map it is easier to see the build-up of the couch and what actions need to precede each other in order to disassemble a component (De Fazio et al., 2021).

In *Figure 25* the different components of the Aikon Lounge '13 are shown, with a numerical indication that is used in *Figure 26 on the next page*.

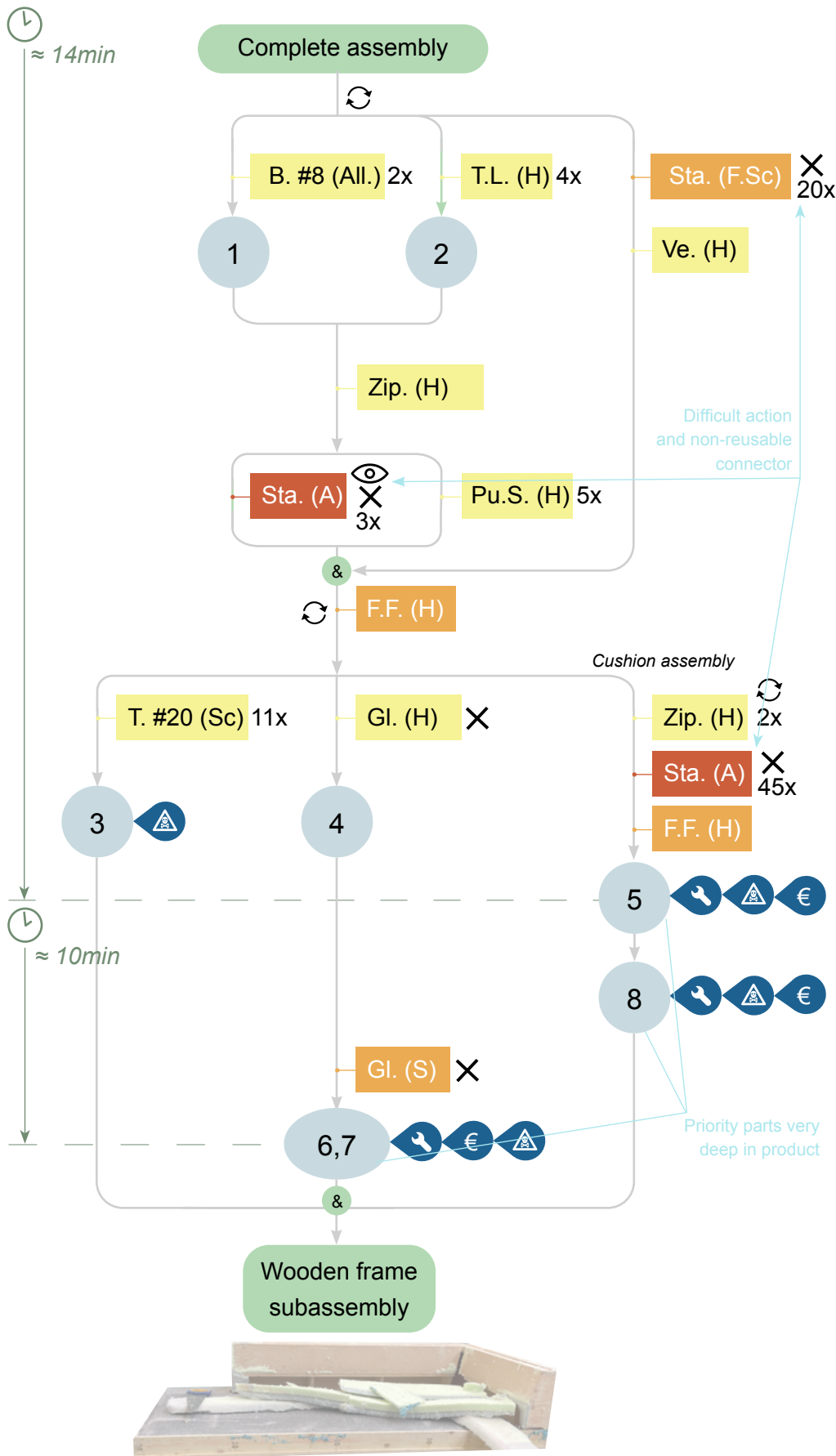
In *Figure 27 on page 44* the total disassembly is visualized.

11.3 Conclusion of the two maps

What we can conclude from the disassembly map is that a lot of the priority parts are buried deep in the product. From the total disassembly time, 30 minutes, getting the fabric cover disassembled and sawing off the foam took the longest, respectively 13,75 minutes and 9,78 minutes.



Figure 25: Different components of Aikon Lounge '13



Legend

Force intensity



Tools

(H) = Hand
 (All.) = Allen key
 (Sc) = Screwdriver
 (F.Sc) = Flathead screwdriver
 (A) = Awl
 (S) = Saw

Connectors

Zip. = Zipper
 Sta. = Staples
 Pu.S. = Pull strips
 B. #8 = Bolt T8
 T. #20 = Torx Screw T20
 Ve. = Velcro
 Gl. = Glue
 F.F. = Friction fit
 T.L. = Turn loose screwthread

Components

1. Extender plate
2. Feet
3. Metal bar
4. Dacron
5. Fabric cover
6. Back foam layer
7. Top foam layer
8. Seat cushion foam

Penalties

↻ = Product manipulation
 👁 = Low visibility
 X = Non-reusable connector

Target components

🔧 = Failure indicator
 🌱 = Environmental indicator
 💰 = Economic indicator

Figure 26: Disassembly map Aikon Lounge '13 disassembly

Figure 27: Disassembly visual overview

Flip couch



Undo cushion strip tacks



Strip & flip



Pull strip from crease

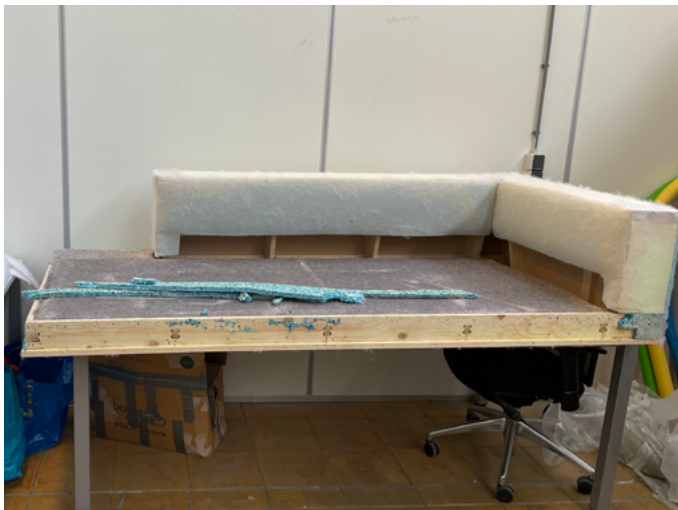


REMOVE UPHOLSTERY

Tool: Hands, awl, flathead screwdriver

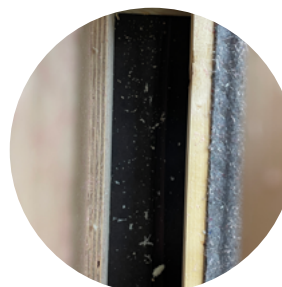
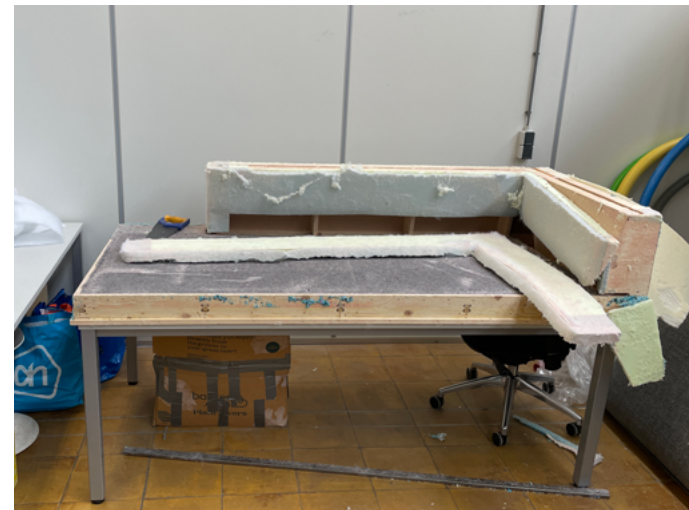


Arm and back upholstery is attached to cushion



REMOVE FOAM

Tool: Saw



Foam residue inside couch frame



MDF plate damage



Harder foam types leave less foam residue

Pulling rebound foam
leaves residue



REMOVE CUSHION

Tool: Hands



REMOVE DACRON

Tool: Hands



REMOVE UPHOLSTERY FROM CUSHION

Tool: Awl



Staples remove partly



Picture of me during disassembly of the couch



EXPLORATION

This chapter aims to explore product design opportunities that can enable couch refurbishment.

These insights are then translated into design directions and tested through iterative design sprints. The most promising solution principles are developed into prototypes and evaluated through comparative tests.

12. WHAT HAPPENS WHEN WE REUPHOLSTER THE COUCH?

During reupholstery of the couch, several practical issues became visible. The process of pulling the fabric back into the right position required a lot of physical effort. The fabric was heavy to handle and there was a lot of tension on the cover, especially around the zipper connection.

One critical point was the zipper in the seat cushion upholstery. This zipper was placed in an area where a lot of tension was present, which made it difficult to close (see *Figure 28*). In addition, the Dacron layer underneath the zipper got caught in the slider, making the process even more difficult (see *Figure 29*).

A row of staples was also found near the zipper (see *Figure 30*). According to a conversation with Jorg, this row of staples was not part of the intended upholstery logic, but was likely added to reduce the tension on the zipper and make closing it easier. This indicates that the current construction already needs an extra corrective step during production to make the upholstery process possible.

The order of assembly was also unclear. The middle zipper had to be closed before the outer zippers, but this was not visible or indicated in the product (see *Figure 31*). To reach this zipper, the right cushion first had to be removed completely. The zipper then had to be inserted into the slider, which was difficult because the fabric was already under tension. When pulling the fabric, the zipper could also come loose again. Only when the zipper was partly closed, the right cushion could be placed back into position. This made the process unintuitive and physically demanding.



Figure 28: Tension on zipper



Figure 29: Dacron in zipper



Figure 30: Where staples were originally placed (orange)



Figure 31: Middle zipper fastening before other steps

Another issue was that different upholstery parts were connected to each other. The backrest upholstery was attached to the seat cushion upholstery, which made it difficult to understand which part of the cover belonged where. It also made the fabric part larger and heavier to handle. Because of this, the assembly and disassembly of one part depended on the position of another part.

13. DESIGN PRINCIPLES FROM REUPHOLSTERY

The reupholstery process in *Chapter 12* led to several design principles for future couch construction.

First, **zippers should not be placed in areas where the fabric is under high tension (see Figure 28)**. In the current couch, the zipper had to close two fabric parts that were already pulling away from each other due to the shape of the cushion. This made assembly difficult, especially where upholstery fabric and dacron met near the zipper.

Second, **upholstery parts should be separated according to the components they cover**. The seat cushion, backrest and main frame should not share one continuous upholstery cover. Instead, they should function as separate upholstered parts. This makes the construction easier to understand and allows one part to be removed without first detaching another. Dutch Quality Group already applies this principle in products such as the Dura Lounge (see *Figure 32*).

Third, **the disassembly sequence should be readable from the product itself**. In the current construction, it was unclear which zipper had to be opened first and which parts had to be removed to access it. Future designs should therefore include a more logical fastening order and clearer access points.

During discussions with DQG, it also became clear that the seat cushion is usually the first component to lose comfort and support. In many refurbishment cases, only the seat cushion foam is replaced, while the backrest and main upholstery remain untouched. Because of this, the ideation phase focused mainly on simplifying seat cushion refurbishment.

The most important recommendation from this phase is therefore to avoid a structural connection between the seat cushion cover and the backrest or frame upholstery. Keeping these parts separate supports faster and more intuitive refurbishment.

At the same time, DQG explained that upholstery fabric is expensive and should be used as efficiently as possible. Connecting upholstery parts can reduce fabric use, but it also increases interdependence between components during refurbishment. The challenge is therefore to separate upholstery parts without unnecessarily increasing fabric consumption.



Figure 32: Dura Lounge couch

14. IDEATION

The ideation phase started with collecting inspiration from existing products, design awards and other sectors. The largest sources of inspiration were the Red Dot Design Award database and the work of design studio LAYER. The collected cases were grouped and visualised in the *Inspiration Atlas*, a separate collection of circular design references I used throughout the ideation phase (uploaded as separate document in this project). Three ideation sessions were then organised, each focusing on a different concept direction.

The two research questions in this phase were:

1. *How can the sequence of disassembly be simplified?*
2. *How can material be saved during refurbishment?*

From these questions, three concept directions were defined:

1. Faster upholstery removal
2. Reversible fastening of foam and fabric
3. Selective replacement of sagged foam

The first and second directions focused mainly on upholstery, while the second and third directions focused on foam.

14.1 Concept evaluation session

A concept evaluation session was organised with Luc and Jorg from Dutch Quality Group (see *Figure 33*).



Figure 33: Luc and Jorg looking at printed sketches

The goal of the session was not to select a final concept immediately, but to understand which ideas they considered most relevant and realistic to develop further within this graduation project. During the session, the ideas within the three concept directions were presented and discussed. These ideas were cut from a large concept poster created as an overview in the ideation phase (see *Figure 34*). The full poster is visible in *Appendix P-F* on page 132.

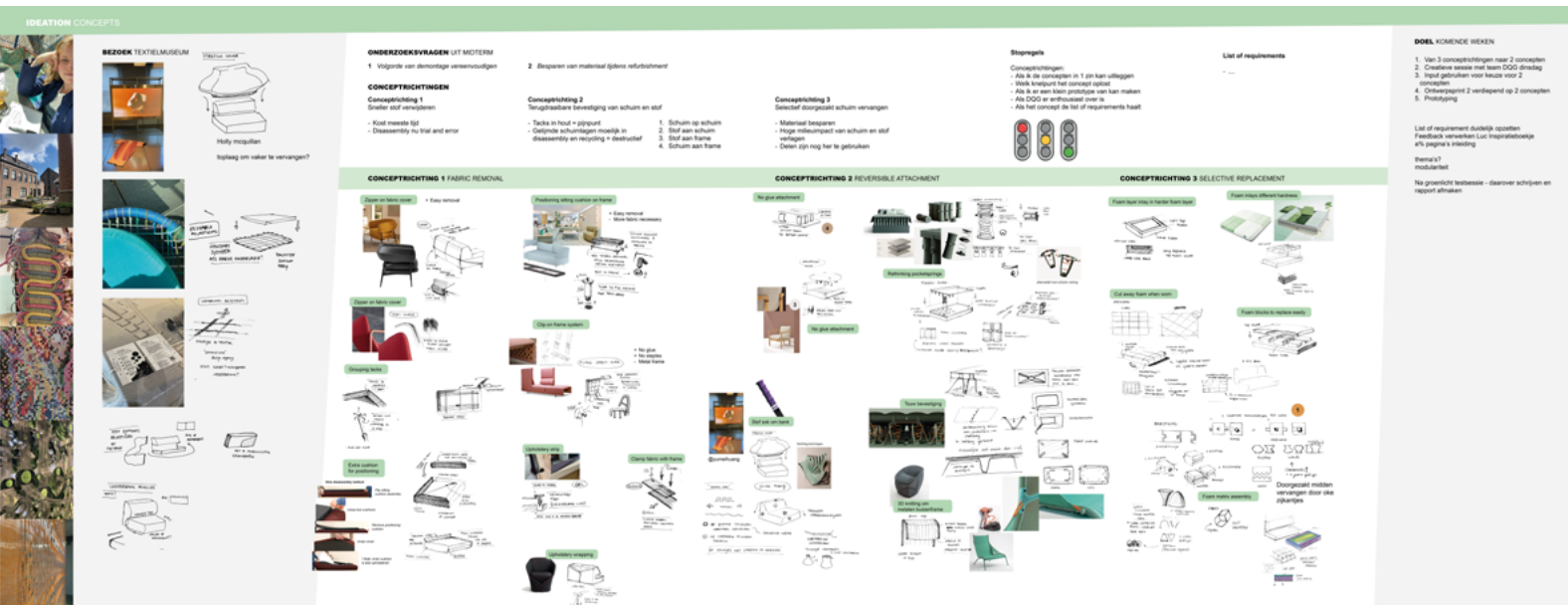


Figure 34: Concept poster

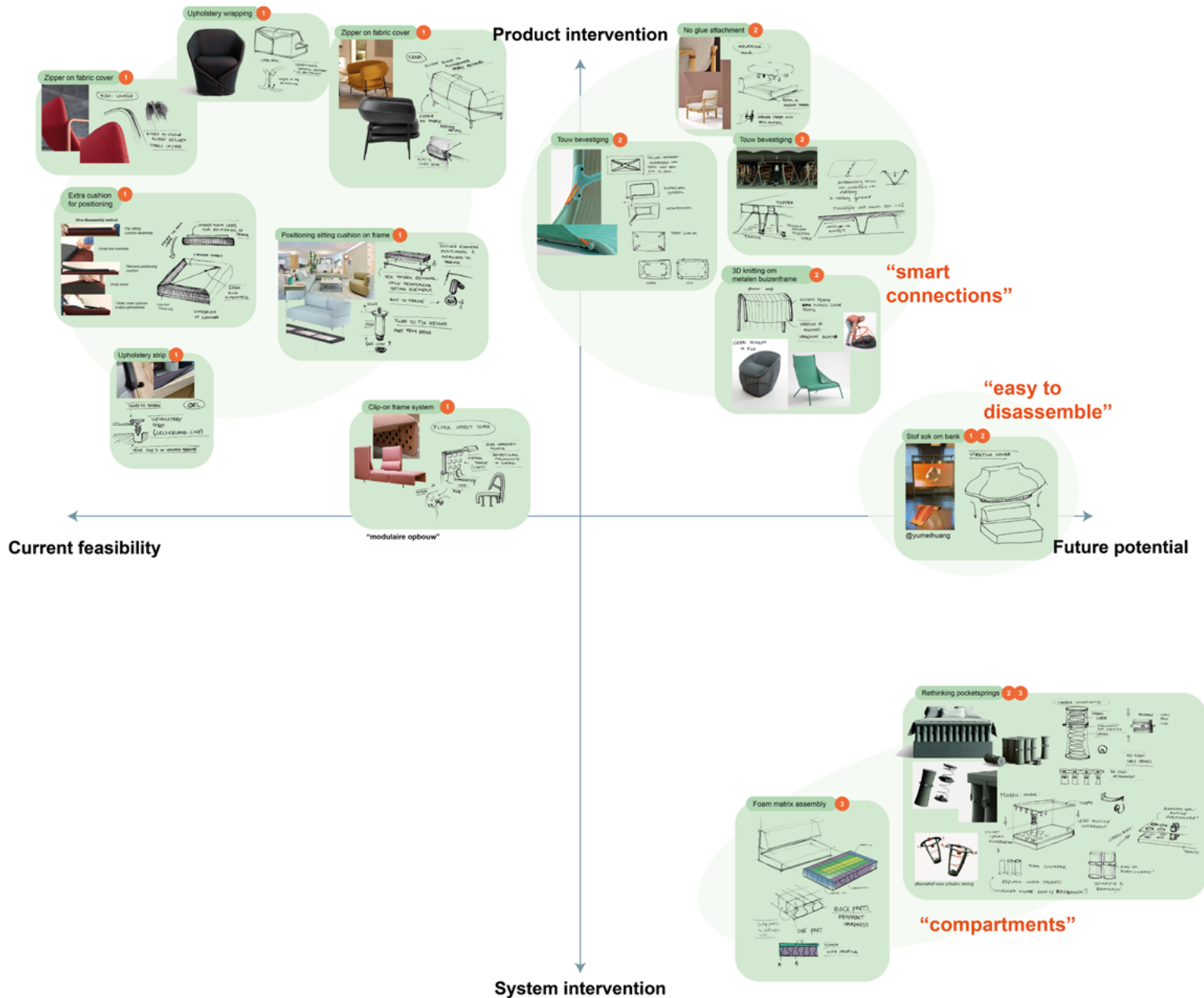


Figure 35: C-box with clustered ideas

14.2 Outcome of the session

The discussion showed that Luc and Jorg mainly evaluated the ideas along two axes. The first axis was **current feasibility versus future potential**. Some ideas were considered directly applicable because they build on techniques that already exist in furniture production, while others were seen as more speculative or future oriented. The second axis was **product intervention versus system intervention**. Based on these two

parameters, a C-box was created to categorise the ideas (see Figure 35). Each idea in the C-box was marked with a number that refers to the concept direction it came from.

Several ideas were filtered out because they were considered less relevant for further development. These ideas are still visible in *Appendix P-G* on page 118. Many ideas were positioned in the quadrant of low threshold product adaptations,

currently feasible on a product level. These ideas were seen as feasible and useful, but also as relatively familiar. Jorg described these ideas as already proven, and Luc noted that the presence of many practical examples showed that these techniques could already be applied.

*“(Left) is actually all proven already”
- Jorg*

They suggested that an Aikon Lounge could be redesigned using these kinds of techniques, but this also meant that these ideas offered less design research value as the main focus of the graduation project.

“Surely we could perfectly well redesign an Aikon Lounge and then apply these kinds of techniques to it?” - Luc

The ideas on the right-hand side of the C-box were considered more interesting for this project, because they represented more fundamental product principles rather than direct detail solutions. These ideas could be grouped into three themes:

- Smart connections
- Easy to disassemble
- Compartments (foam)

The clusters are shown enlarged to present the ideas, see Figure 36, Figure 37 and Figure 38.

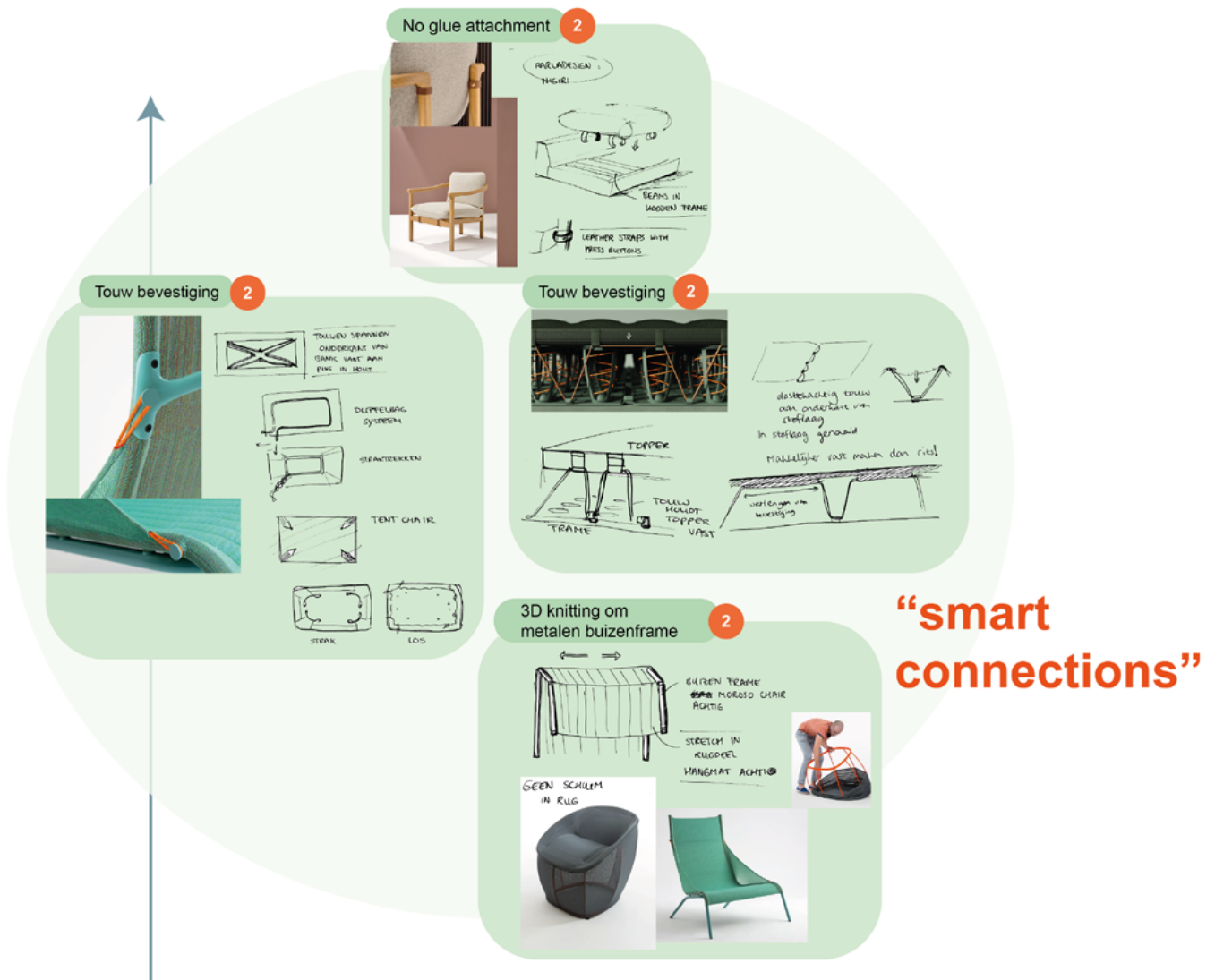


Figure 36: Cluster 1, smart connections

“easy to disassemble”

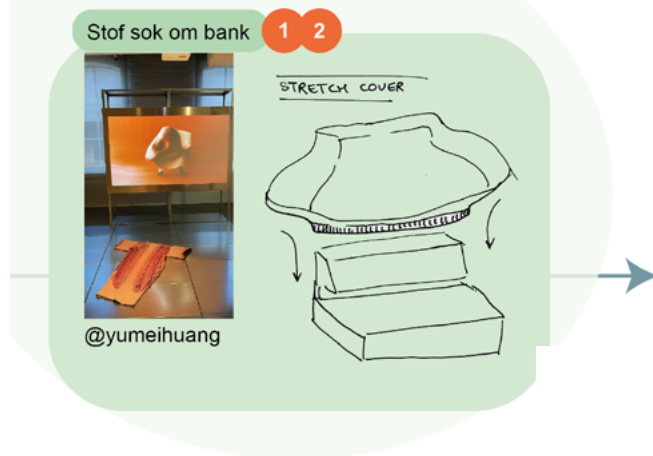


Figure 37: Cluster 2, easy to disassemble

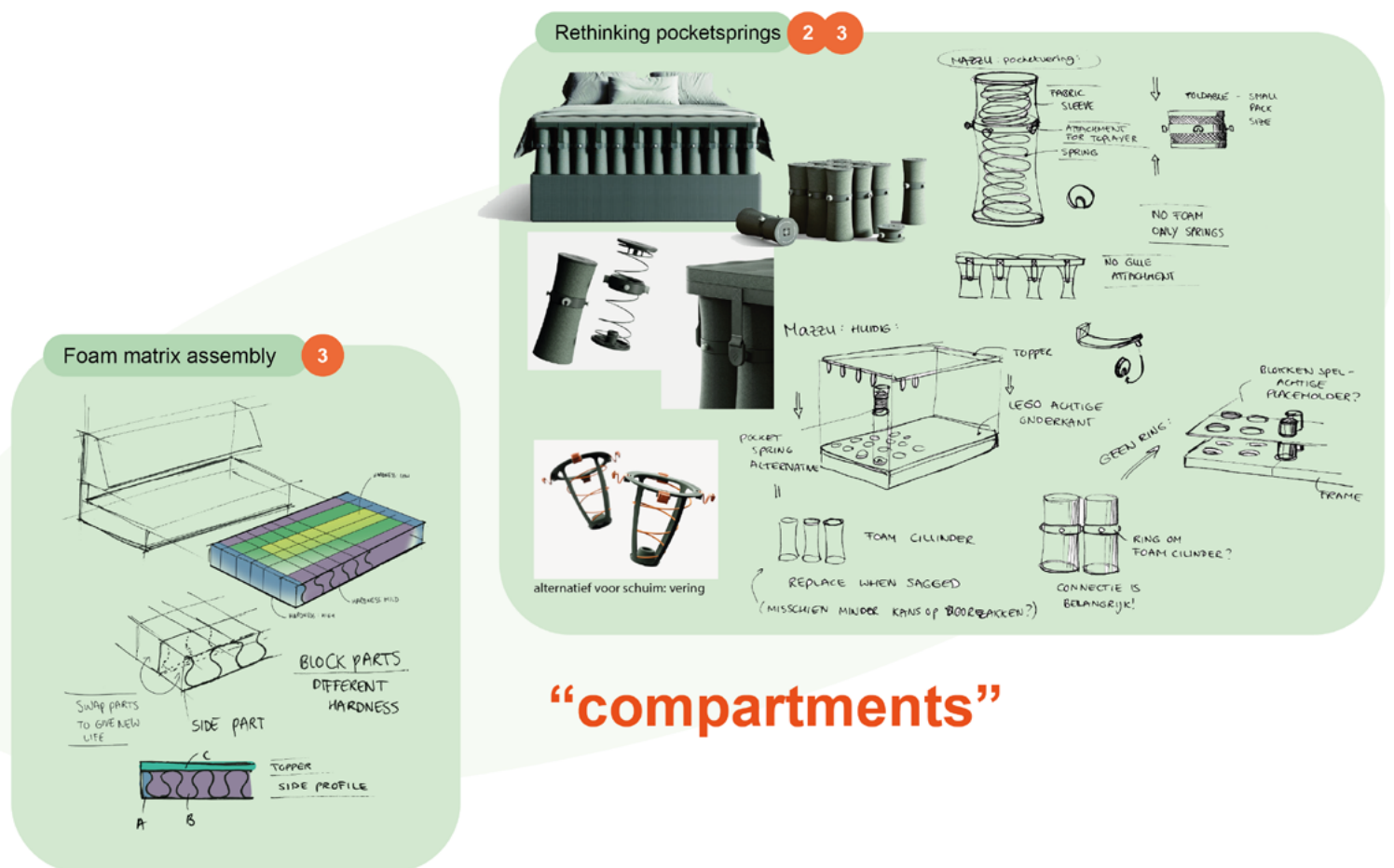


Figure 38: Cluster 3, compartments (foam)

Luc grouped the cord based ideas under fastening and tensioning principles. These ideas were interesting because they could replace pulling, stapling or difficult zipper connections with a more reversible way of tensioning the upholstery. The foam compartment ideas were seen as a separate direction, because they could change the way foam is built up and replaced.

The stretch sleeve, based on 3D knitting or stretch textile, was also discussed as an interesting idea. However, it was positioned more as a future direction. Luc referred to it as a “2035” concept, while Jorg indicated that it would need specific textile development knowledge. Desk research was performed to the feasibility of stretch textile on a couch with the research question:

Can a stretch upholstery fabric stay under long term tension on a couch without losing shape, tension, appearance or abrasion resistance? The result is presented in Figure 39 on the next page.

14.3 Choice of concepts

Based on the discussion and the desk research, two directions were selected as most relevant for the next phase: a reversible tensioning or fastening principle for upholstery, and a compartment based foam principle. These directions respond directly to the two research questions. The reversible fastening concept focuses on simplifying the disassembly sequence, while the foam compartment concept focuses on reducing material use by enabling selective replacement of worn foam parts.

14.4 Presentation of two concepts

The two concepts are shown on page 58 and 59.

14.5 Proof of concepts

In the development of the concepts, Jorg emphasised that the project should search for simplicity and realistic feasibility. He also stated that volume needs to be taken into account in the design, especially when working with foam or textile structures.

“But I think, to find something that succeeds, we really need to look for simplicity.”

“The volume really needs to be taken into account in the design.” - Jorg

Stretch sleeve feasibility

The stretch sleeve concept depends strongly on the long term performance of stretch upholstery fabric. For this concept, the fabric would not only need to stretch over the couch once, but stay stretched around the couch for a long period of time, while also being exposed to friction from sitting, sliding and cleaning. This makes the application different from stretch clothing, where the fabric is regularly stretched and relaxed.

The most important fabric properties are permanent stretch, elastic recovery, creep, abrasion resistance and pilling.

Stretch can be defined as the ability of a fabric to extend without breaking, but also as the ability to return to its original shape after stretching (Refiber Designs, n.d.). For the stretch sleeve, this second definition is most important.

Literature on textile creep shows that when a textile is stretched for a long time, it may not fully return to its original shape afterwards (Urbelis et al., 2005). This does not prove that a stretch couch cover will deform, but it does show that long term tension retention would need to be tested.

Stretch behaviour also depends strongly on the exact fabric. Kaynak (2017) found that elastane draw ratio, applied load and relaxation type influence stretch and permanent stretch properties. This means that the feasibility of the concept cannot be judged based on “stretch fabric” in general. The specific material would need to be tested under couch-like conditions.

A couch is exposed to repeated friction, especially on the seat, armrests and front edge. Shaw and Mukhopadhyay (2021) found that abrasion can reduce elasticity, elastic recovery and shape retention in stretch fabrics. For upholstery applications, fabrics also need to meet high abrasion requirements, often tested with the Martindale method.

Based on this desk research, the stretch sleeve is not impossible, but uncertain. It responds to a relevant problem, because fabric removal is a critical disassembly hotspot. However, the concept depends on a fabric that needs to perform under long term tension and repeated abrasion. A quick prototype could show whether the cover can be pulled over the couch, but it would not prove whether the fabric keeps its shape, tension and appearance over several years of use. Therefore, the stretch sleeve is considered more suitable as a future material research direction than as the main concept to prototype in this graduation project.

Figure 39: Desk research stretch sleeve feasibility

Current problem scenario:

Couch foam sags after years of use. In the couch 1 or 2 sagging spots appear where the fabric starts showing wrinkles over the sagged foam.

Current use scenario:



The couch is brought for refurbishing (reupholstery), where the foam is cut off and thrown away or the couch is brought to the waste incineration, where it is burned.

New use scenario:



The cushion is opened, the worn blocks are removed. New blocks are inserted. The cushion is closed and placed in the couch. The couch is ready for another 4-5 years of use.

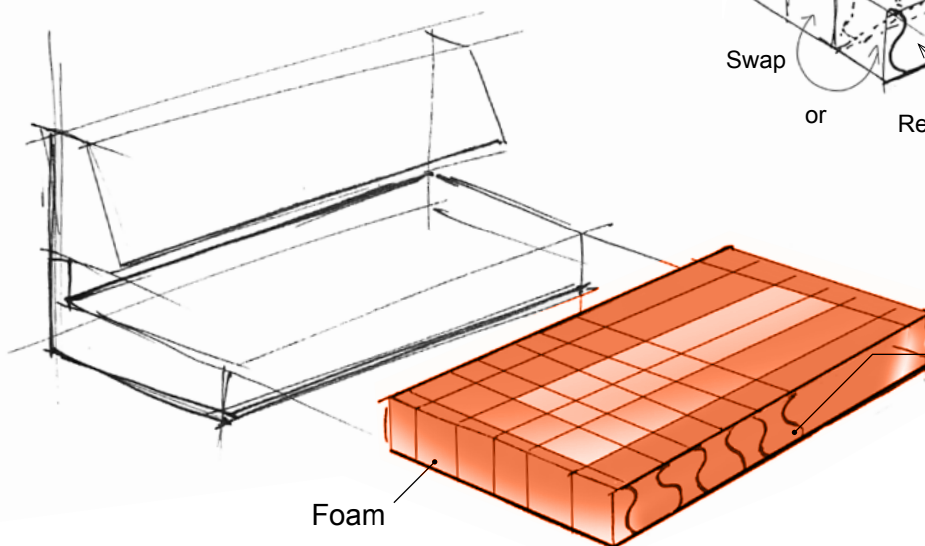
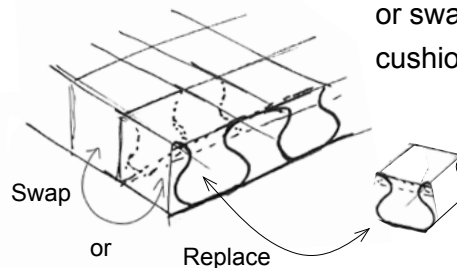
FOAM COMPARTMENTS

How does it work?

Replaceable foam blocks with interlocking geometry

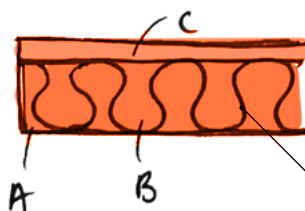
Concept assumption: the geometry keeps the blocks together without glue.

Worn blocks can be replaced or swapped before the full cushion fails



Foam

Interlocking shape prevents blocks from shifting sideways



Possible buildup:

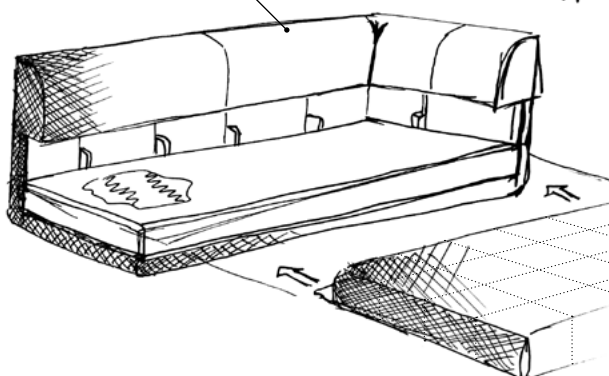
A = harder foam

B = normal foam

C = toplayer foam

Optional: different hardnesses can create comfort zones

Upholstered couch frame



After upholstering, the compartment cushion is placed back into the couch frame

Current problem scenario:

The upholstery fabric is fixed with staples or permanent fasteners. During refurbishment, the fabric has to be pulled loose, which takes time and can damage the textile, foam or frame.

Current use scenario:



The couch is brought in for refurbishment. The upholstery has to be removed manually. Staples are taken out one by one, and the cover cannot easily be reinstalled in the same way.



New use scenario:

The upholstery is tensioned with a cord instead of staples. During refurbishment, the cord is loosened, the cover is opened and the foam can be accessed. After replacement, the cover is pulled tight with the same cord system.

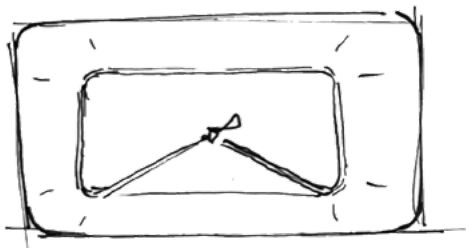
PULLCORD FABRIC COVER

How does it work?

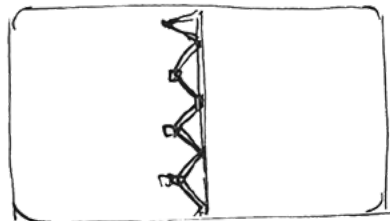
A reversible way to tension upholstery without permanent staples.

Concept assumption: The cord can create enough fabric tension to keep the upholstery tight, while still allowing the cover to be loosened for refurbishment.

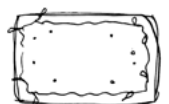
Possible fixation: knot, hook, cord lock or cleat



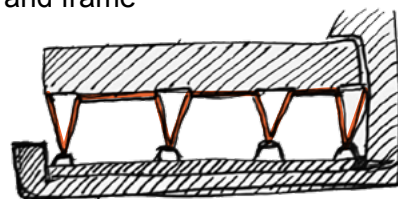
Cord pulls fabric tight underneath frame, loosen cord to access foam and frame



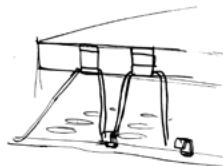
Fastened



Loose



Pullcords that pull the cushion or fabric to pins in the couch frame



Cord tunnel sewn into fabric edge



Elongating the cord tunnel that the cord runs through prevents unwanted marks in the fabric

Different fastening options can be explored

14.5.1 Foam concept

The next step was to create a proof-of-concept to test whether the foam compartments could be made with the interlocking geometry. The first design was a 'kruik' (jug) shaped geometry that could be flipped to fit in the shape of the neighbouring block (see *Figure 40*). A SolidWorks model was created to explore how different blocks with this geometry would fit when placed together in a grid (see *Figure 41*). During this process, an important issue appeared. The original 'kruik' shaped geometry created holes in the corners where four blocks met (see *Figure 42*).

This led to a new geometry with a continuous wave shape on all sides of the block (see *Figure 43*). In *Figure 44* the geometry is visualized in a grid. Because the geometry repeated itself equally on each side, the corner gaps disappeared. Ideation continued with this wave geometry.

To quickly test the principle on a small scale, a 3D printed prototype was made (see *Figure 45*). The blocks were printed with the wave geometry from *Figure 43* and assembled into a 4x4 grid, consisting of inner blocks, flat outer blocks and corner blocks. The blocks could be placed inside

an open box to test how they interacted when compressed together. After closing the box, the middle block could be pulled to evaluate whether the interlocking geometry prevented movement between the blocks.

The test showed that the geometry was able to reduce movement between neighbouring blocks.

14.5.2 Pullcord concept

For the pullcord concept, the expertise of the factory was consulted. The concept was developed into a clear sketch and production approach, after which it was stitched by someone from the DQG factory.

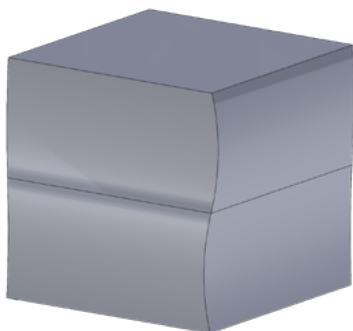


Figure 40: 'Kruik' block

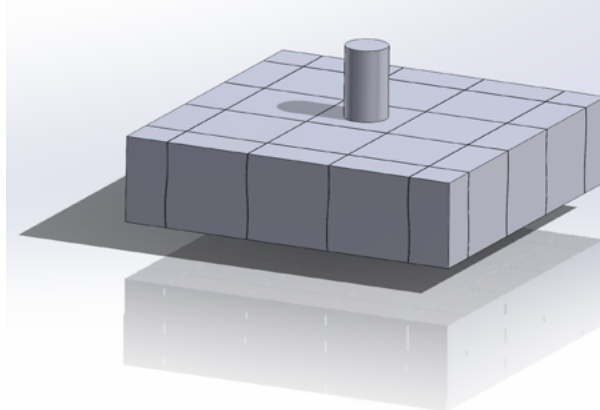


Figure 41: 'Kruik' geometry in grid

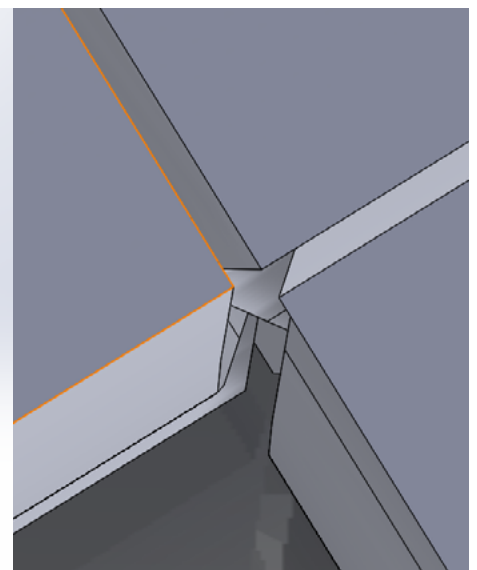


Figure 42: Holes in corners of 'kruik' geometry

14.6 Testing the foam blocks

The foam compartments were developed in foam into a Minimal Viable Product (MVP) that was tested by sitting on the foam and monitoring its behaviour. This procedure is shown in Chapter 16.

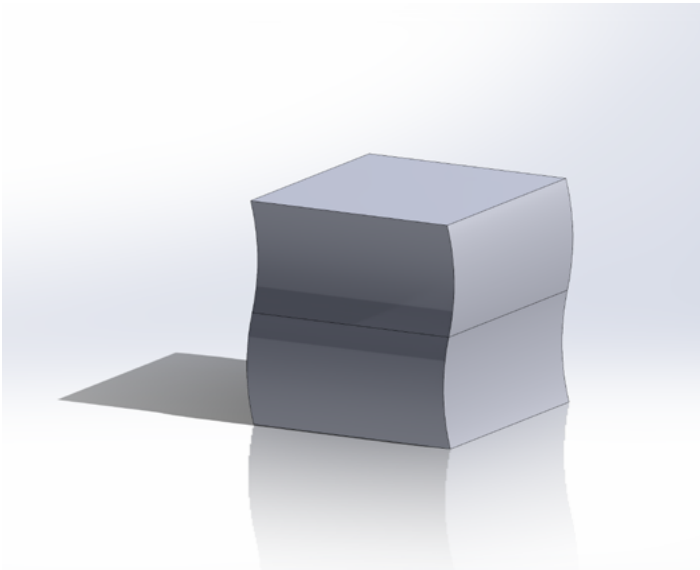


Figure 43: 'Wave' block

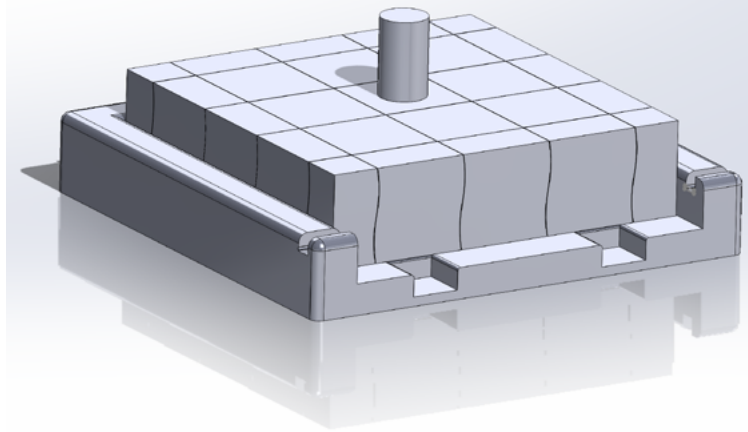


Figure 44: Assembly of iterated wave geometry

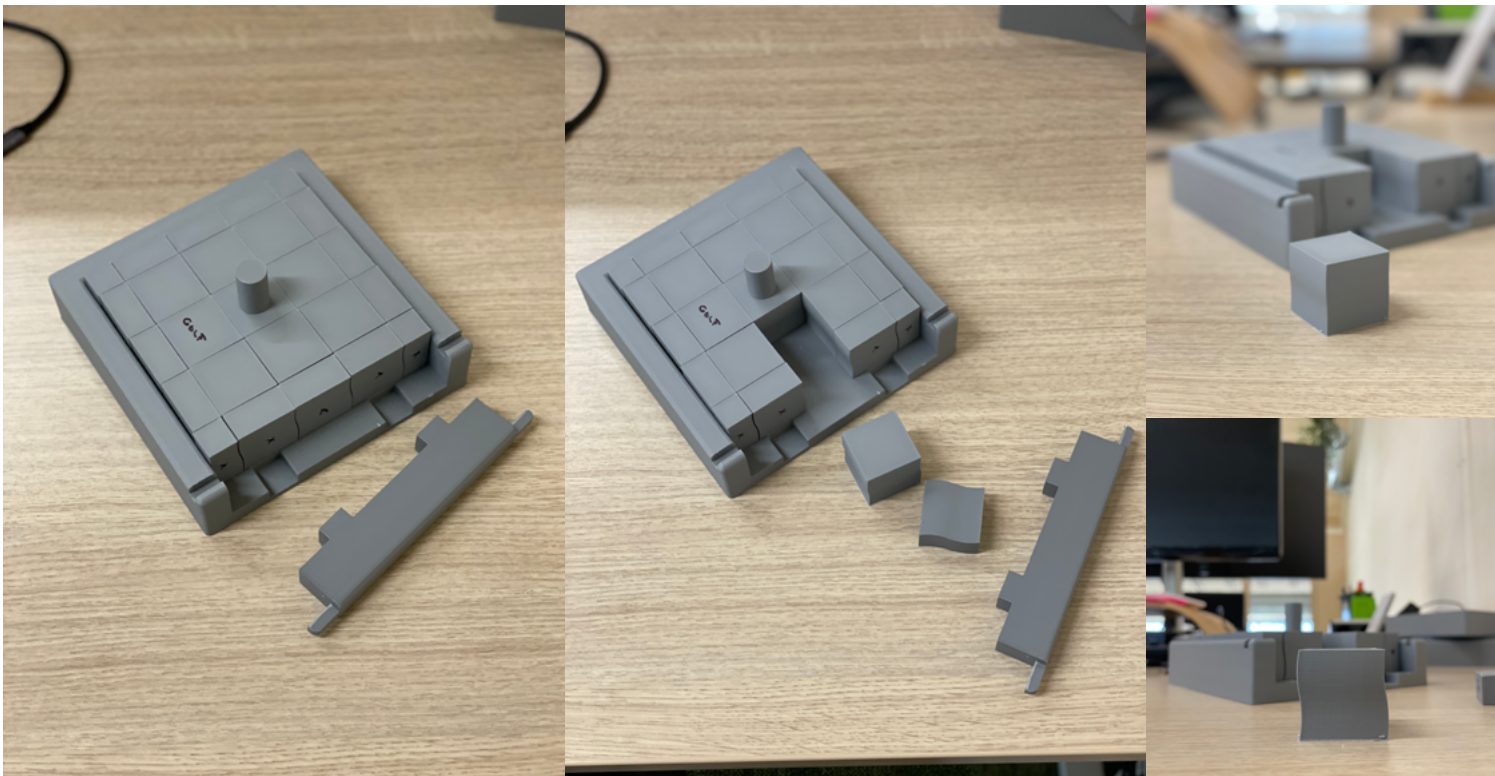


Figure 45: 3D printed blocks to make a proof of concept

15. LIST OF REQUIREMENTS

The following requirements were defined to evaluate the feasibility of the demonstrator cushion. The requirements focus on three areas: the functional performance of the concepts, the impact on production and refurbishment processes, and the performance of the final demonstrator during use. All requirements were formulated to be measurable, so the concept could be evaluated through prototyping and testing.

Functional requirements:

1. The demonstrator must allow one foam compartment to be removed independently without removing neighbouring compartments.
2. A removed foam compartment must be reinstallable within 2 minutes.
3. The foam compartments may not show visible displacement larger than 10 mm after the sitting test.
4. Foam compartments and upholstery must be removable without destructive actions such as cutting, tearing or breaking components.
5. The refurbishment time must be reduced by at least 50 percent compared to the current glued foam construction.
6. The redesign must reduce the ecological impact of one refurbishment cycle by at least 50 percent compared to replacing the full cushion.
7. The cushion architecture must enable up to 3 refurbishment cycles without replacing the complete cushion build up.

Production requirements:

8. The foam geometry must be producible using accessible production methods such as CNC cutting, guided sawing or comparable techniques.
9. The replacement process of one foam compartment must take less time than fully stripping glued foam from a cushion base.
10. The redesign may not increase production time by more than 5 minutes per cushion.

Demonstrator requirements:

11. The cushion surface may not show visible height differences larger than 5 mm after the sitting test.
12. The seams between compartments may not be visible from 1 meter distance under normal lighting conditions (in the demonstrator cushion).
13. The seams between compartments may not be immediately noticeable while sitting for at least 3 test users.
14. The demonstrator may not show tearing, detachment or structural failure after 20 sitting cycles and 1 rotation test.

16. TEST METHOD

16.1 Aim

The aim of the test is to compare three foam compartment geometries in a simplified cushion setup. The test investigates whether the blocks stay in place during use, whether seams become visible, and whether the cushion surface changes after sitting.

Because these aspects are strongly influenced by geometry, cutting accuracy and the cushion build up, the concept was explored through an iterative Research through Design process. The prototypes were not only used to validate a fixed solution, but also to learn which geometry and setup could make the concept feasible.

Three cushion samples were made:

- Vertical wave geometry
- Square block geometry
- Horizontal wave geometry

Each cushion sample has the same basic build up (see Figure 46).

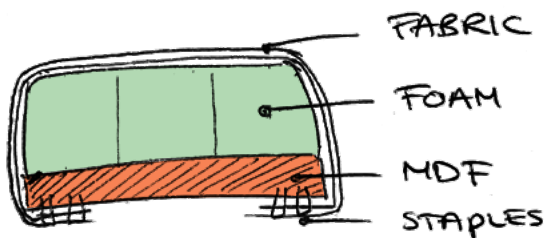


Figure 46: Buildup cushion sample

This makes the samples more realistic than testing loose foam blocks, because the upholstery tension also influences the stability of the blocks.

16.2 Research questions

The foam compartment tests were guided by four research questions (see Figure 47).

16.3 Test procedure

Each cushion was tested in the same way:

1. Take a photo before testing
2. Sit down on the cushion 20 times
3. Sit on the cushion for 1 minute
4. Rotate on the cushion while seated
5. Take a photo after testing
6. Compare before and after photos
7. Score the cushion on the test criteria

16.4 Testing criteria

The test criteria were used to compare the different geometries and to decide which direction should be developed further. The criteria were derived from the list of requirements presented in Chapter 15 and were adapted to fit a Harris profile evaluation.

- Blocks stay in place after sitting
- Cushion surface remains unchanged
- Easy to remove one part
- Easy to assemble
- Visibility of seams before sitting
- Visibility of seams after sitting
- Seams are not felt during sitting
- Easy to manufacture

The photos are used as visual evidence to compare the surface before and after use. The sitting sequence is used as a simple repeatable load test, not as a full durability test.

1. Can the foam blocks stay in place when the cushion is compressed, loaded and used repeatedly?
2. Can one block be removed and replaced without damaging the surrounding blocks or the cushion build up?
3. Are the seams between the blocks visible or noticeable when sitting on the cushion?
4. Can the geometry be produced without creating excessive complexity, waste or dependency on one specific production method?

Figure 47: Research questions

17. PROTOTYPE APPROACH

Before the sitting test could be performed, three cushion samples had to be made. This required developing a way to cut the foam blocks, arrange them into a compartment layer, and upholster them onto an MDF base.

The making process became iterative, because the first geometry and cutting setup revealed practical problems. These problems led to an adjusted geometry and a new cutting setup. The aim of the setup was not to create a final production method, but to produce test blocks accurately enough to compare different geometries.

17.1 Cutting setup

A cord saw was selected to cut the curved foam geometries, because a flexible saw can follow non linear cutting paths (see *Figure 48*).

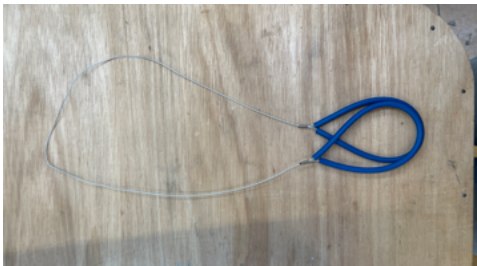


Figure 48: Cord saw tool

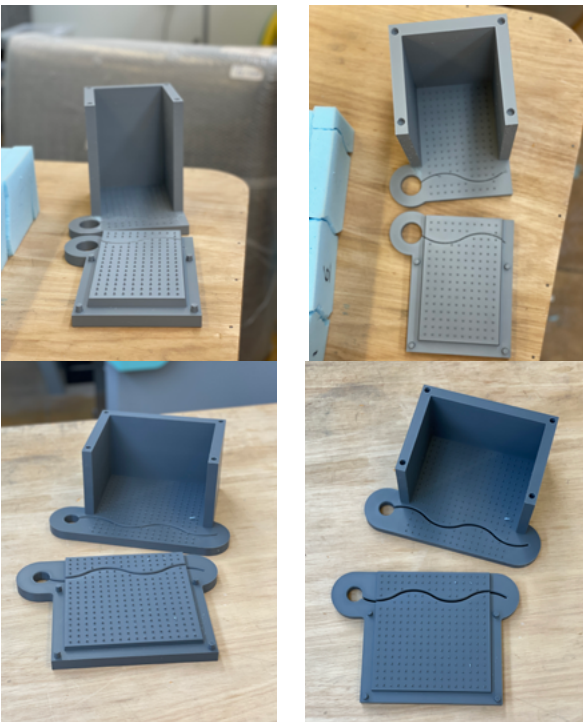


Figure 49: Cutting setups vertical (top) and horizontal (bottom)

To be able to control the cut of the curved path, a cutting guide was designed in SolidWorks and 3D printed (see *Figure 49*). The ideation that led to the cutting setup is visualised in *Appendix P-I* on page 138.



Figure 50: Cutting setup horizontal with foam block

The foam block was placed inside the guide and compressed 5 mm by the lid, then positioned on the workbench with clamps (see *Figure 50*). This was done to reduce movement during cutting. Silicone spray was applied on the plastic box to reduce friction with the foam while sliding the block in. Spikes were modeled on the top and bottom of the inside of the box to keep the foam block in place while cutting. The first cutting setup aimed at cutting the block in the vertical direction (see *Figure 49 (top)*), while the iterated setup cut the block in the horizontal direction (see *Figure 49 (bottom)*).

17.2 Cushion build up

All test cushions were made with the same basic construction, as shown in *Figure 46*. An MDF plate was used as the base. The foam blocks were placed on top of the MDF in the selected geometry. After positioning the foam blocks, fabric was pulled over the foam and stapled to the underside or edge of the MDF.

This setup was chosen because it creates a simplified version of a real cushion. The MDF base fixes the underside, while the stretched fabric applies pressure over the foam blocks.

17.2.1 Sample A, vertical wave cushion

The first cushion sample was made with a vertical wave geometry. The aim was to create wave shaped side surfaces between neighbouring blocks to prevent vertical shifting of the blocks and to keep stiffness of the foam during compression. The block geometry is visible in *Figure 51*.

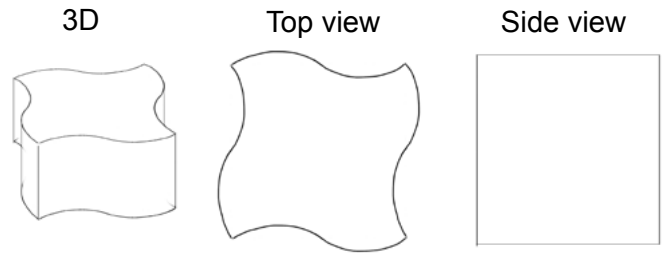


Figure 53: Geometry sample C

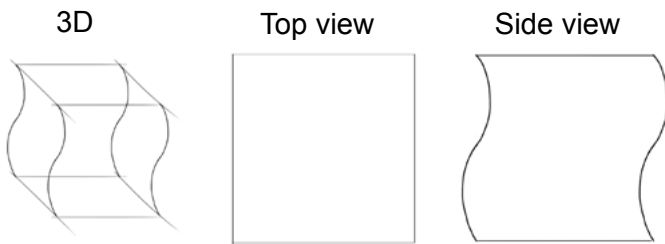


Figure 51: Geometry sample A

17.2.2 Sample B, square block cushion

The second cushion sample was made with square foam blocks. This sample was added as a reference. The blocks were cut with straight edges on a band saw and arranged in a grid on the MDF base.

The square geometry was included because it is the simplest version of a compartment cushion (see *Figure 52*).

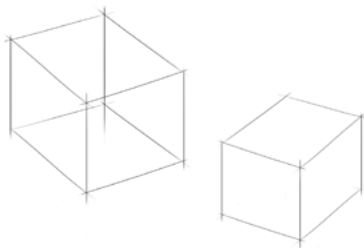


Figure 52: Geometry sample B

17.2.3 Sample C, horizontal wave cushion

The third cushion sample was made after the first wave geometry showed limitations during cutting. A new cutting setup was developed to create a horizontal wave geometry.

In this version, the wave was placed in a different direction to keep more consistent block width (see *Figure 53*).

18. SITTING TESTS RESULTS

18.1 Test execution

Each cushion sample was photographed before testing. The same sitting sequence was then performed on each sample: sitting down 20 times, sitting for 1 minute, and rotating on the cushion while seated. After this sequence, each sample was photographed again. The before and after photos were compared to fill in a Harris Profile.

18.2 Test results per sample

On the next page the results of the different tests are shown.

Picture of me sawing the foam block in the horizontal cutting guide



18.2.1 Results sample A, vertical wave

Making the foam blocks in this geometry appeared to be difficult, since the entry of the cord saw in the foam pushed the foam away and created deformations in the wave geometry. The result is that the top square became smaller than planned. This created bigger seams and uneven surfaces on the sides. The result of creating these blocks sparked the decision to create another testing setup with a horizontal wave.

After the sitting test, the surface of the vertical wave cushion showed no signs of movement,

except for the outer blocks, they shifted down. The compartment lines were already quite visible before the test and after the test the change was limited. The blocks appeared to stay well together. During sitting, the cushion felt firmer than Sample C and as firm as Sample B. Assembly is difficult because the blocks need to be assembled in a specific orientation to fit. Thus, the main issue with this sample was the ease of removing one part from the others and the ease of assembly.

[illegible]

Criteria

1. Blocks stay in place after sitting
2. Cushion surface remains unchanged
3. Easy to remove one part
4. Easy to assemble
5. Visibility of seams before sitting
6. Visibility of seams after sitting
7. Seams are not felt during sitting
8. Easy to manufacture

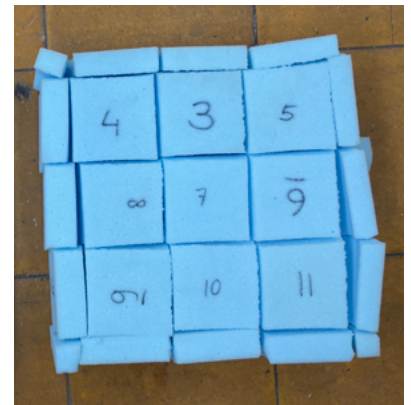


Figure 58: Block grid assembly

Figure 54: Harris profile Sample A



Figure 55: Sample A before sitting test



Figure 56: Sample A after sitting test

Shift of block, fabric gathers
in the seams

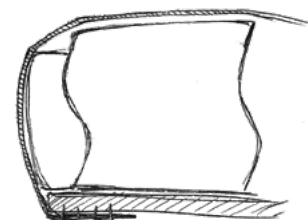


Figure 57: Behaviour of foam sketch

RESULTS SITTING TESTS

18.2.2 Results sample B, square blocks

After the sitting test, the square block cushion showed signs of blocks movement. Without loading the cushion, the inner 9 cubes stayed compressed, probably due to friction with the outermost blocks. The grid structure was more visible through the fabric after the sitting test. During sitting, the cushion felt firm. The main issue with this sample was the change in cushion surface and the visibility of the seams.

- -	-	+	++

Figure 59: Harris profile Sample B

- Criteria
- 1. Blocks stay in place after sitting
 - 2. Cushion surface remains unchanged
 - 3. Easy to remove one part
 - 4. Easy to assemble
 - 5. Visibility of seams before sitting
 - 6. Visibility of seams after sitting
 - 7. Seams are not felt during sitting
 - 8. Easy to manufacture

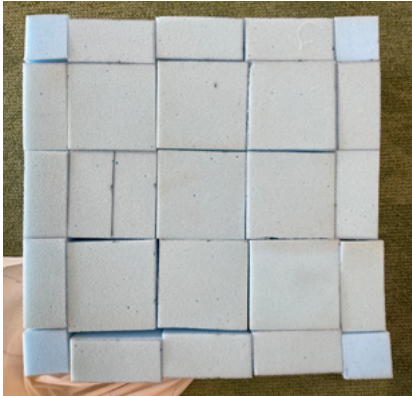


Figure 63: Block grid assembly



Figure 60: Sample B before sitting test



Figure 61: Sample B after sitting test

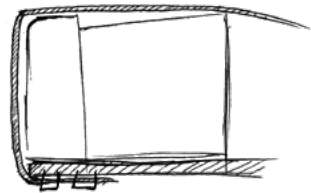


Figure 62: Behaviour of foam sketch

18.2.3 Results sample C, horizontal wave

After the sitting test, the horizontal wave cushion showed block shifting similar to sample B. The compartment lines were more visible after the test, and the tips of the geometry started pointing upwards in the fabric cover. During sitting, the cushion felt softer than the other samples, which was an unexpected result, since all samples were made from the same foam. The main issue with this sample was the shifting of the blocks after sitting.

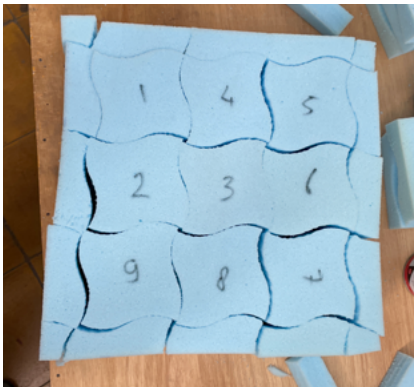


Figure 67: Block grid assembly

- -	-	+	++

- Criteria**
- 1. Blocks stay in place after sitting
 - 2. Cushion surface remains unchanged
 - 3. Easy to remove one part
 - 4. Easy to assemble
 - 5. Visibility of seams before sitting
 - 6. Visibility of seams after sitting
 - 7. Seams are not felt during sitting
 - 8. Easy to manufacture

Figure 64: Harris profile Sample C



Figure 65: Sample C before sitting test



Figure 66: Sample C after sitting test

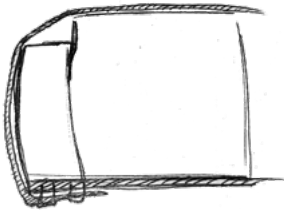


Figure 68: Behaviour of foam sketch

RESULTS SITTING TESTS

18.3 Comparison of results

The three samples show that foam geometry influences both production and cushion behaviour. Although all samples were made from the same foam, they did not feel the same while sitting. This means that the difference in firmness was caused by the geometry, not by the material.

The first four criteria are most relevant for selective foam replacement. Criteria 7 “Seams are not felt when during sitting” was removed because all three concepts scored the same. The seam criteria were less decisive, because all samples showed some seam visibility. In a real cushion, an added topper and Dacron layer would likely reduce this.

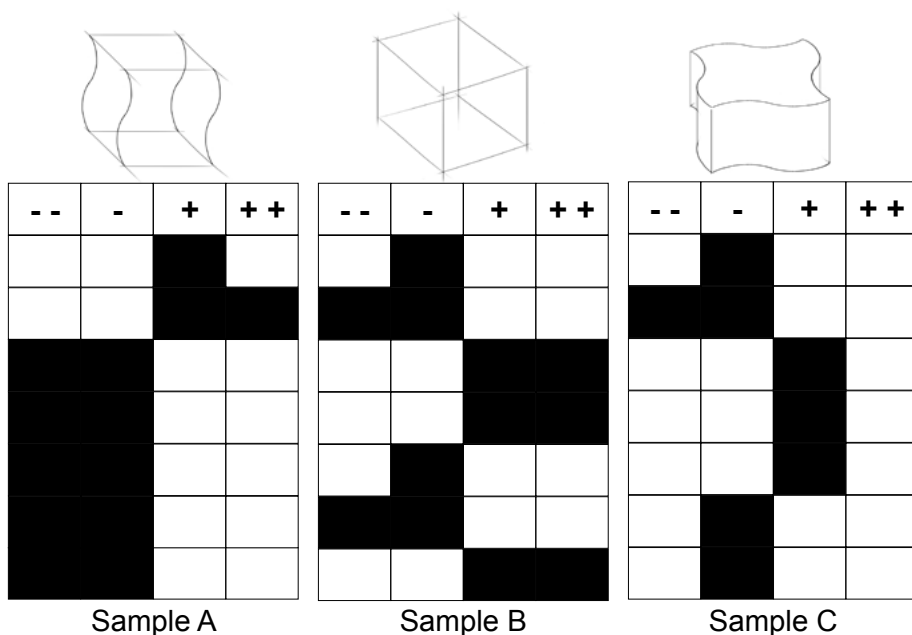
Sample A showed that the vertical wave can keep blocks together, but it was difficult to make accurately. The cord saw pushed the foam during cutting, which deformed the wave shape. This created larger seams and an uneven surface. The blocks also had to be placed in a specific orientation, which made assembly and replacement less intuitive.

Sample B performed best overall. The square blocks were easy to cut, assemble and understand. The inner blocks stayed mostly in

place after sitting, and the cushion felt firm. The main issue was that the cushion surface changed after use and the seams became more visible. This could likely be improved by using a smaller MDF base and adding the normal cushion layers.

Sample C showed that the horizontal wave made the cushion feel softer, even though the same foam was used. The geometry allowed more local movement between the blocks. After sitting, the blocks shifted more than expected and the wave points became visible through the fabric. This makes the geometry less suitable in its current form.

Based on this comparison, sample B is the most promising direction for the next test. It does not create mechanical interlocking, but the combination of friction, compression and fabric tension already kept the blocks mostly in place. It is also the easiest option to produce and replace. The next test should focus on the full cushion build up instead of a more complex block geometry. A smaller MDF plate, a topper layer and Dacron should be added to test whether the seams become less visible and whether the blocks stay better in place.

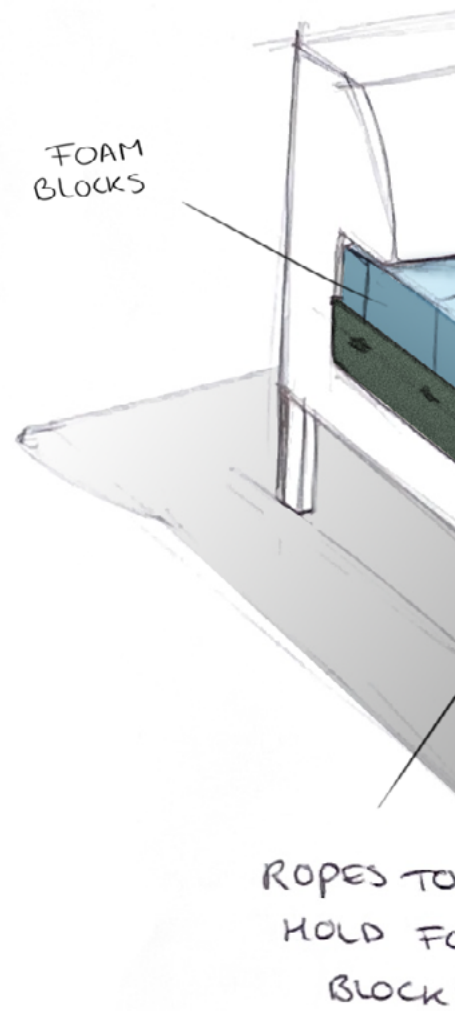


1. Blocks stay in place after sitting
2. Cushion surface remains unchanged
3. Easy to remove one part
4. Easy to assemble
5. Visibility of seams before sitting
6. Visibility of seams after sitting
7. Easy to manufacture



Picture of me sitting on the upholstered cushion for the test

FINAL DESIGN



19. FINAL DESIGN SKETCHES

19.1 Final design

Figure 69 shows the buildup sketch of the final design.

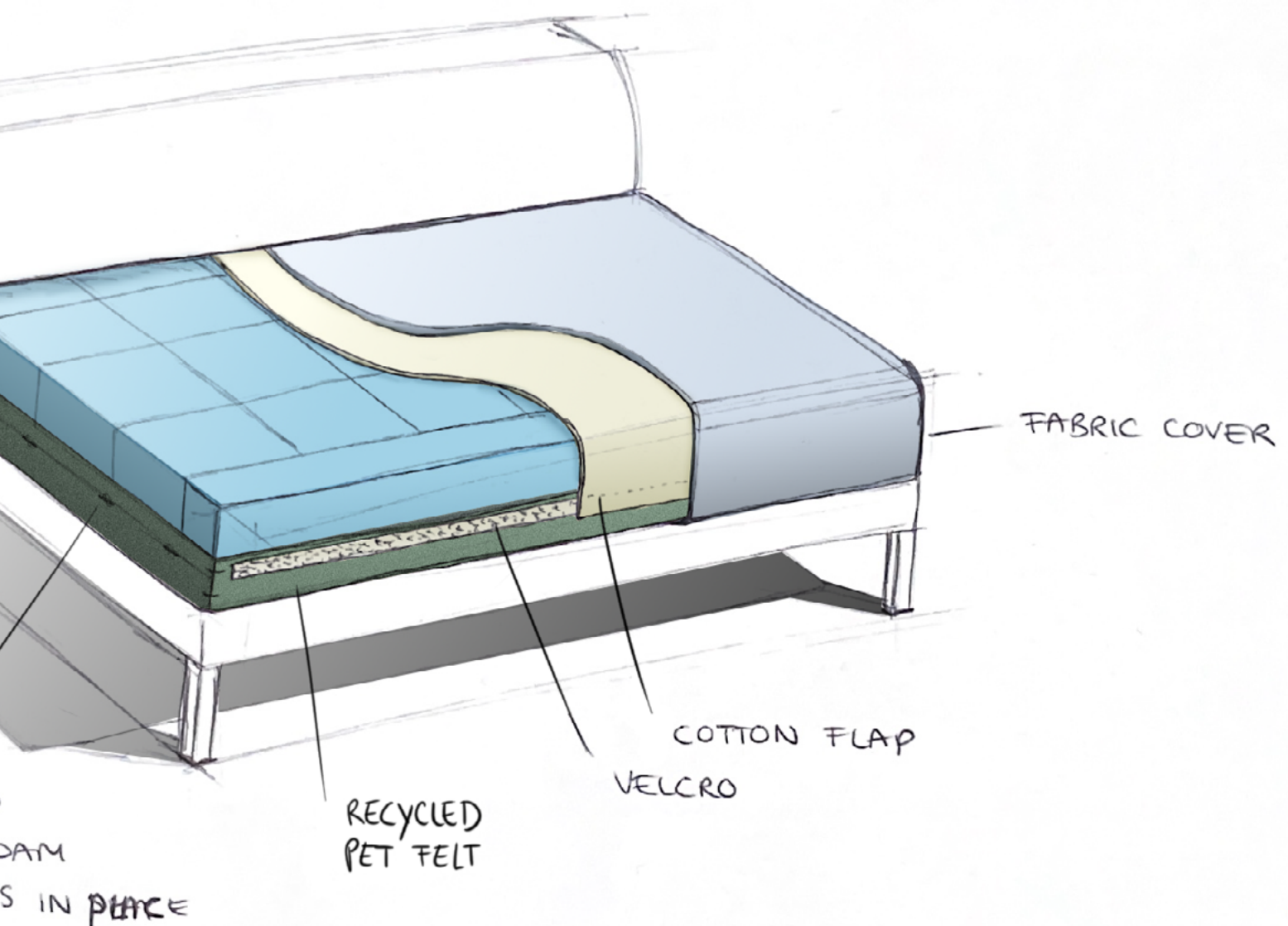
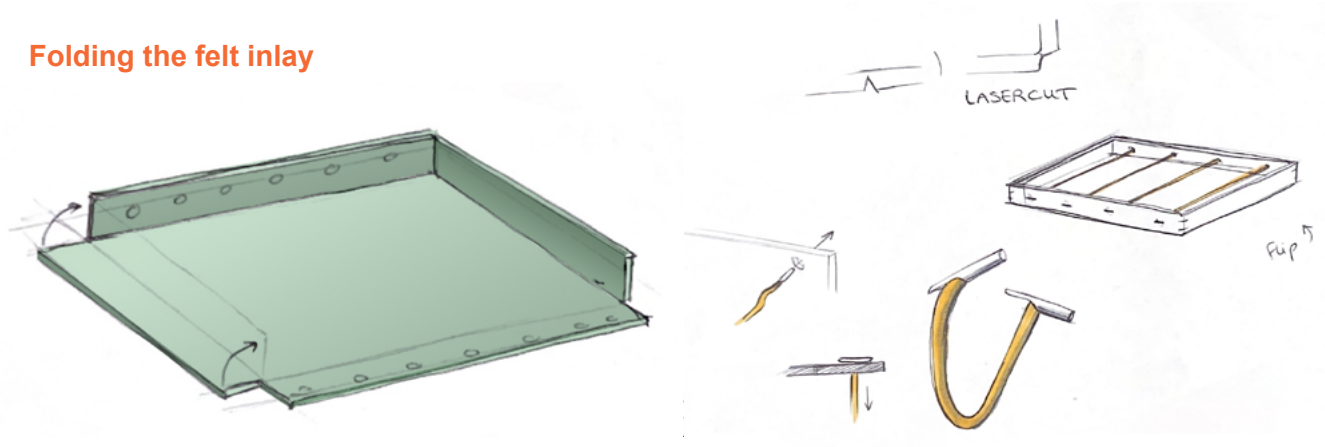


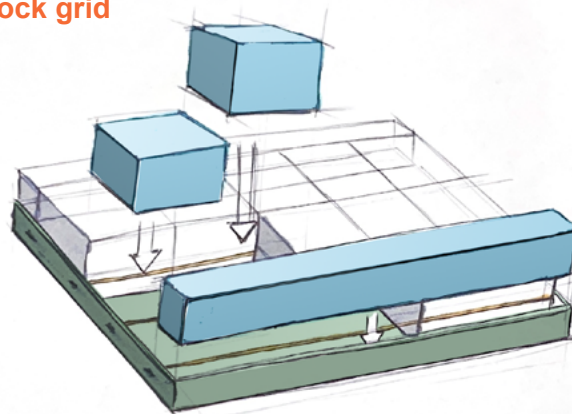
Figure 69: Final design sketch

FINAL DESIGN SKETCHES

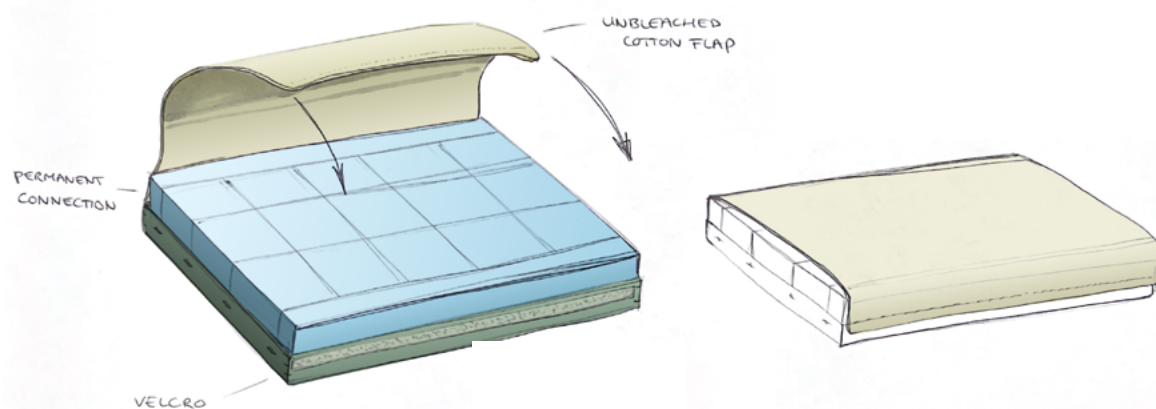
1 Folding the felt inlay



2 Placing the block grid



3 Pulling the cotton flap



4 Upholstering the cushion

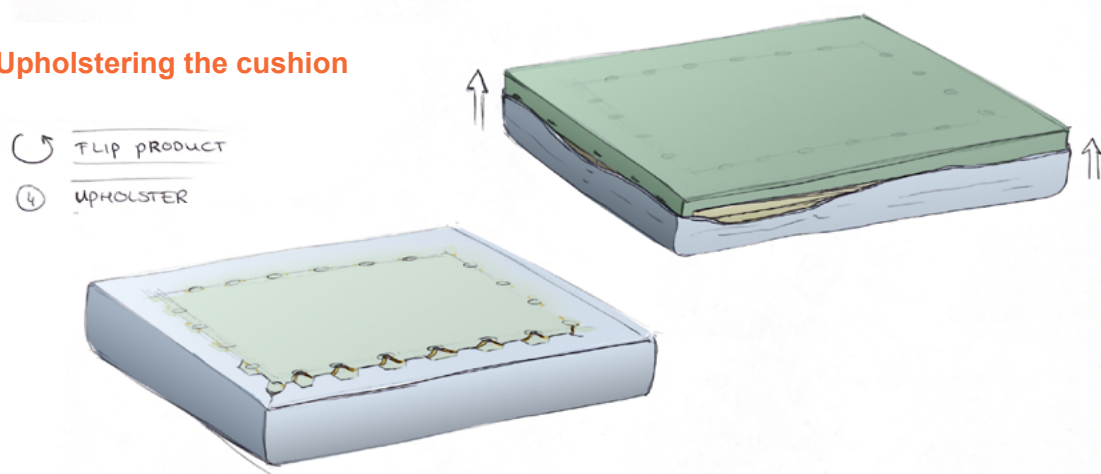


Figure 70: Assembly steps 1 to 4 of the final design

5

Tightening the pullcord

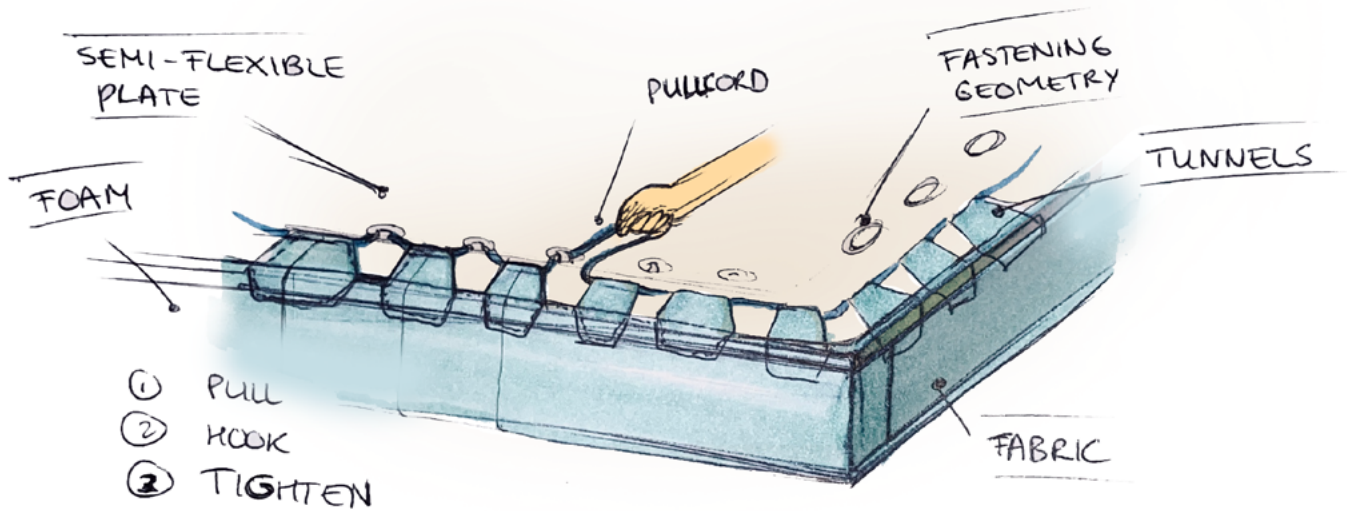


Figure 71: Assembly step 5 final design

19.2 Upholstery steps of final design

In Figure 70 and Figure 71 the five steps are displayed that assemble and upholster the final design, with the pullcord cover (see Figure 72 for pullcord details) and the foam blocks.

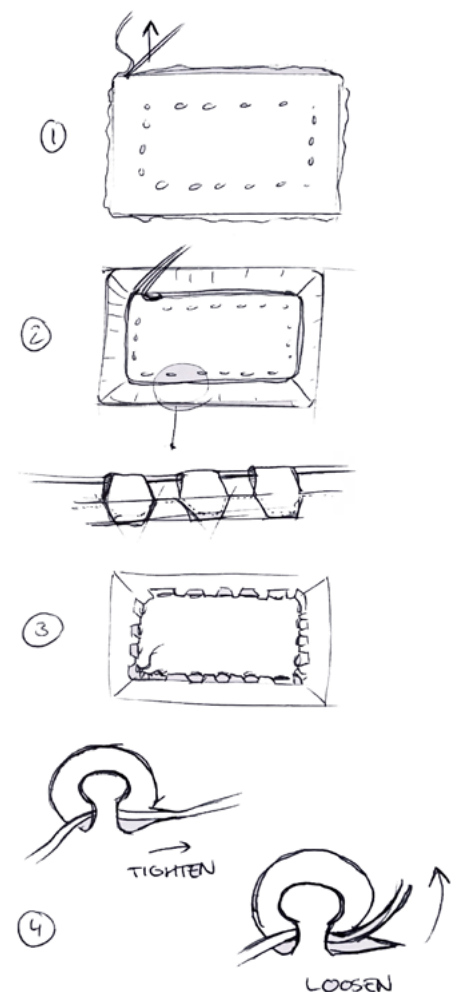


Figure 72: Details of pullcord design

20. FINAL DEMONSTRATOR CUSHION

20.1 Design goal

The final design demonstrates how a couch cushion can be redesigned to make foam replacement and upholstery access faster and less destructive. The design combines two principles: a compartment based foam cushion and a reversible upholstery tensioning system.

The aim is not to present a production ready couch, but to show how refurbishment could work when foam, fabric tension and fastening are designed as accessible layers instead of hidden, glued or stapled connections.

20.2 Overview of the final demonstrator

The demonstrator consists of a cushion build up with individual foam blocks placed inside a supporting inlay. Around this build up, the upholstery is tensioned with a cord system instead of permanent staples. This makes the foam layer accessible after loosening the cord.

The demonstrator therefore brings together the two concept directions developed earlier in the project:

1. Selective replacement of foam compartments.
2. Reversible tensioning of the upholstery cover.

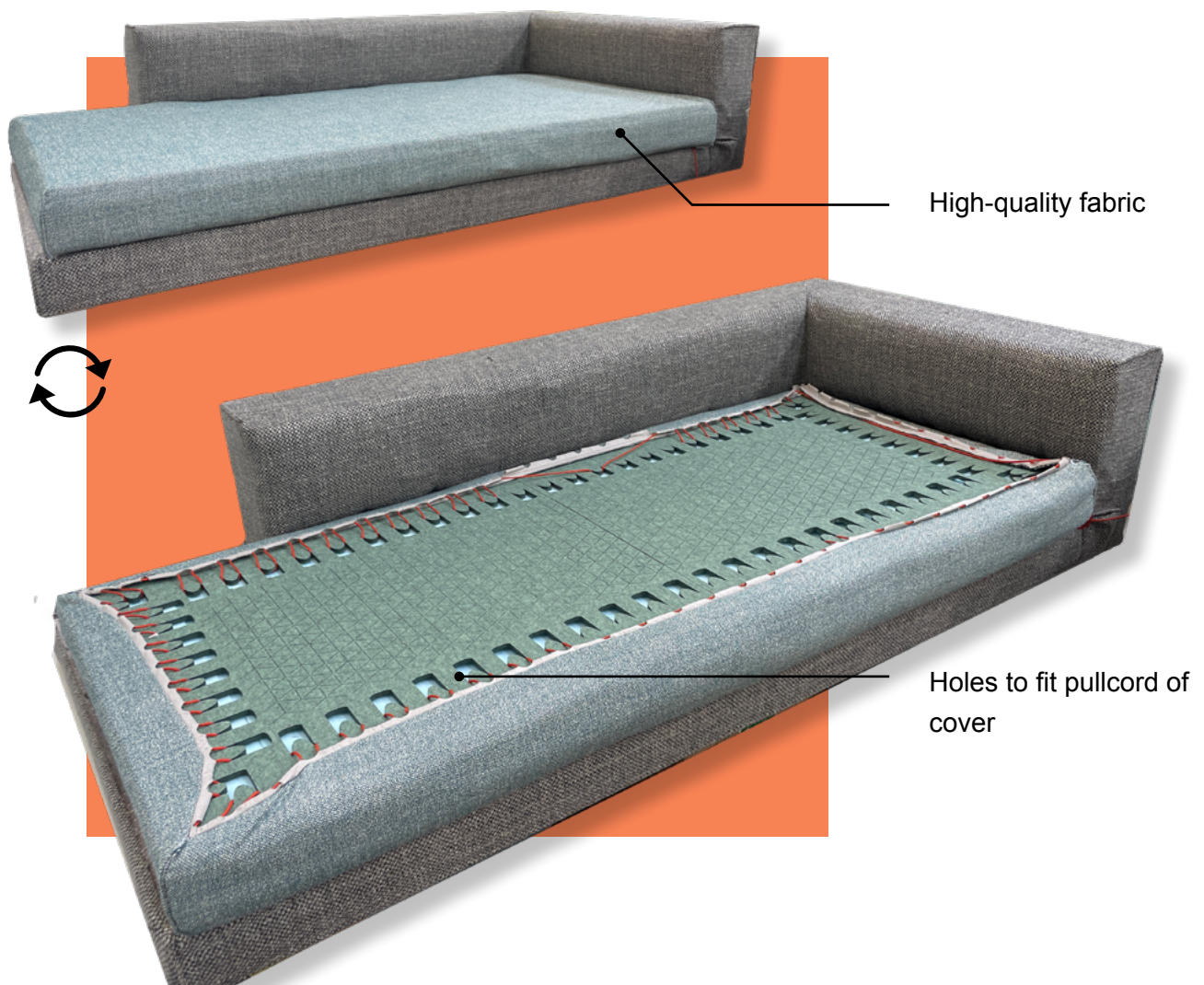


Figure 73: Final demonstrator



Figure 74: Felt inlay assembled

FINAL DEMONSTRATOR CUSHION

20.3 Foam compartment design

Instead of one glued foam volume, the cushion is divided into separate foam blocks. This allows one local area of worn foam to be removed, swapped or replaced without discarding the full cushion.

The square block geometry was selected because it performed best in the earlier tests. It was easier to produce, easier to assemble and easier to understand than the wave geometries. The blocks measure 15 cm by 15 cm by 11 cm, achieving a balance between precise replacement and fast manufacturing.

Tensioned paracords keep the felt inlay in shape and create indications where the foam blocks need to be placed

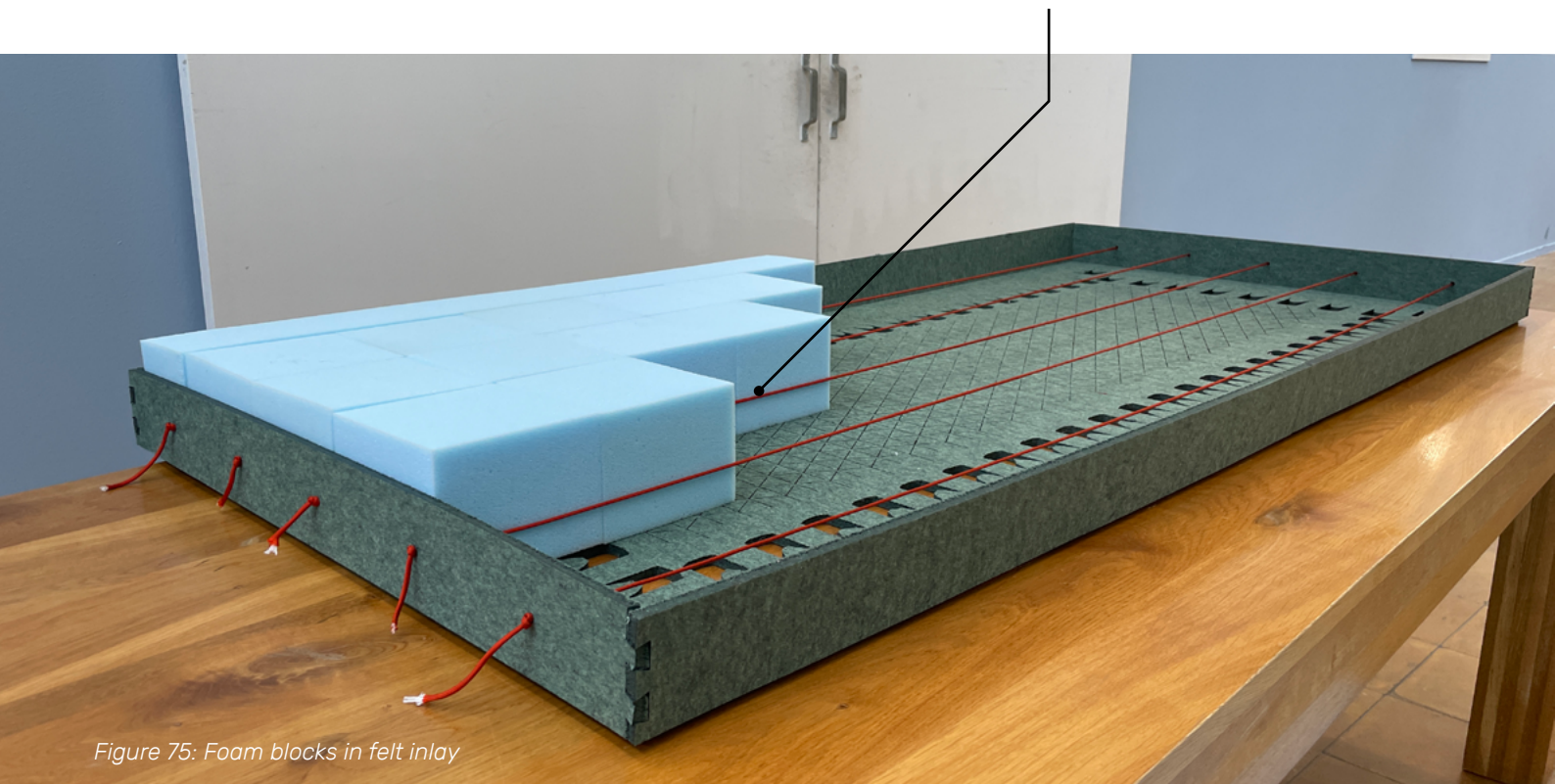


Figure 75: Foam blocks in felt inlay



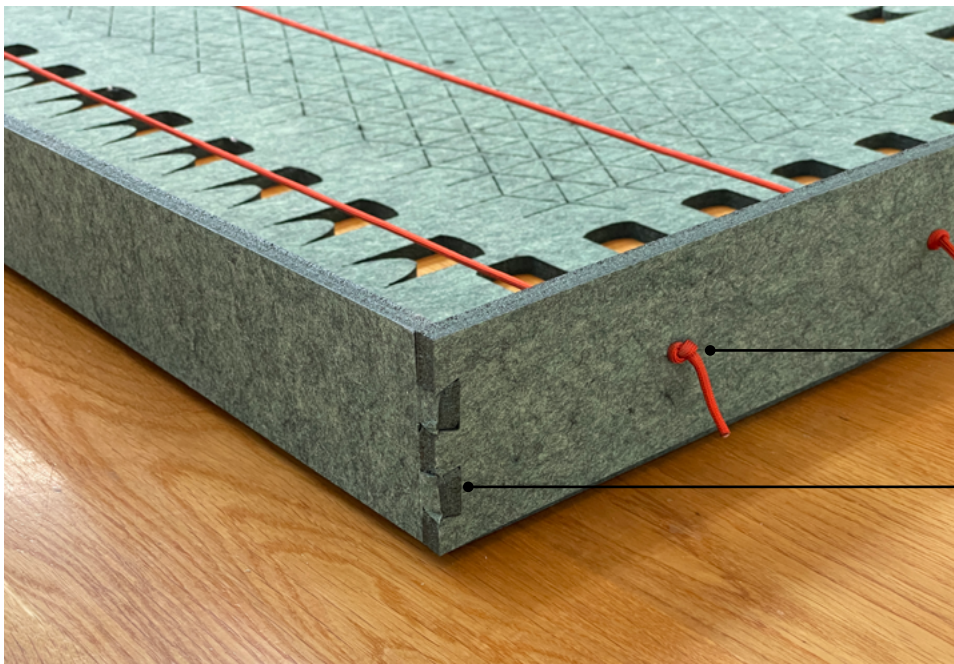
Figure 76: Foam blocks in felt inlay

20.4 Felt inlay for positioning and stability

The foam blocks are placed inside a 100% recycled PET felt inlay that keeps them positioned during use. This inlay prevents the blocks from moving sideways and makes the cushion easier to upholster. It also gives the foam compartments a clear location, making replacement more controlled during refurbishment.

The pullcord is a paracord 550 type III, which is approximately 4mm thick. It is smooth and comfortable while pulling it.

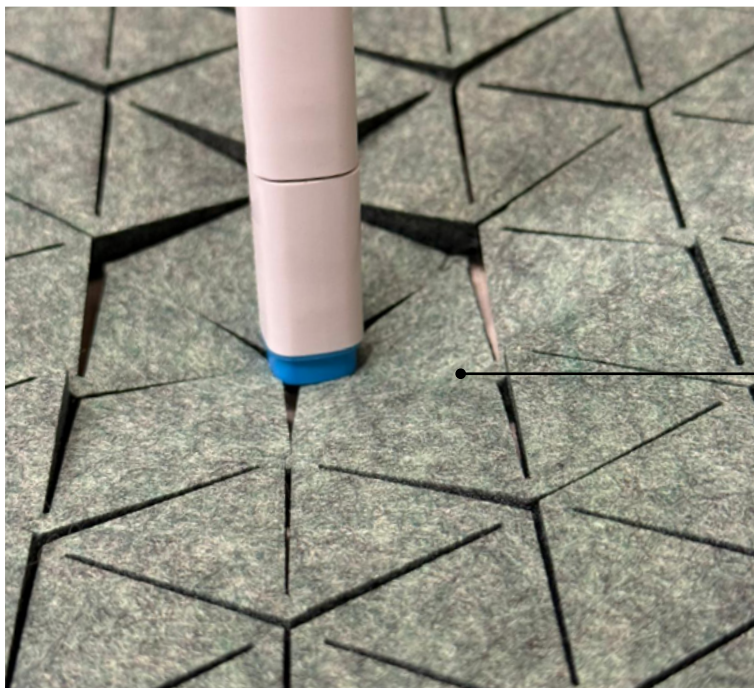
The triangular pattern in the middle ensures more flexibility to enhance the force on the foam to be transferred through the felt plate towards the nosag springs.



Paracord to separate foam blocks

Interlocking geometry to prevent use of glue

Figure 77: Felt inlay side detail and pullcord attachment



Triangular pattern to make plate more flexible

Figure 78: Felt inlay pattern under load

20.5 Reversible upholstery tensioning

The upholstery cover is tensioned using a paracord that runs through a sewn tunnel. By pulling the cord and hooking it around its corresponding anchor, the fabric is tightened around the cushion. By loosening the cord, the cover can be opened again without damaging the fabric or frame. The anchors are shaped so that the sides (where the pullcord enters) have a clamping effect.

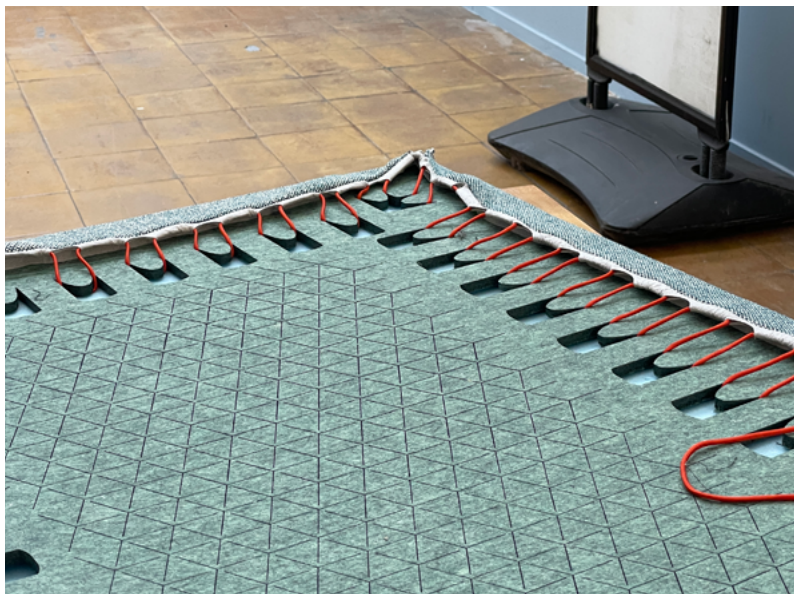


Figure 79: Tightening sequence of pullcord

Hook...



...and pull



Figure 80: Tightening sequence of pullcord

20.6 Refurbishment sequence

The demonstrator shows a possible refurbishment sequence, visible in *Figure 81*. First, the cord is loosened. Then the upholstery cover can be opened. The foam blocks become accessible,

after which blocks can be removed and replaced. Finally, the cover is closed and tensioned again with the cord.

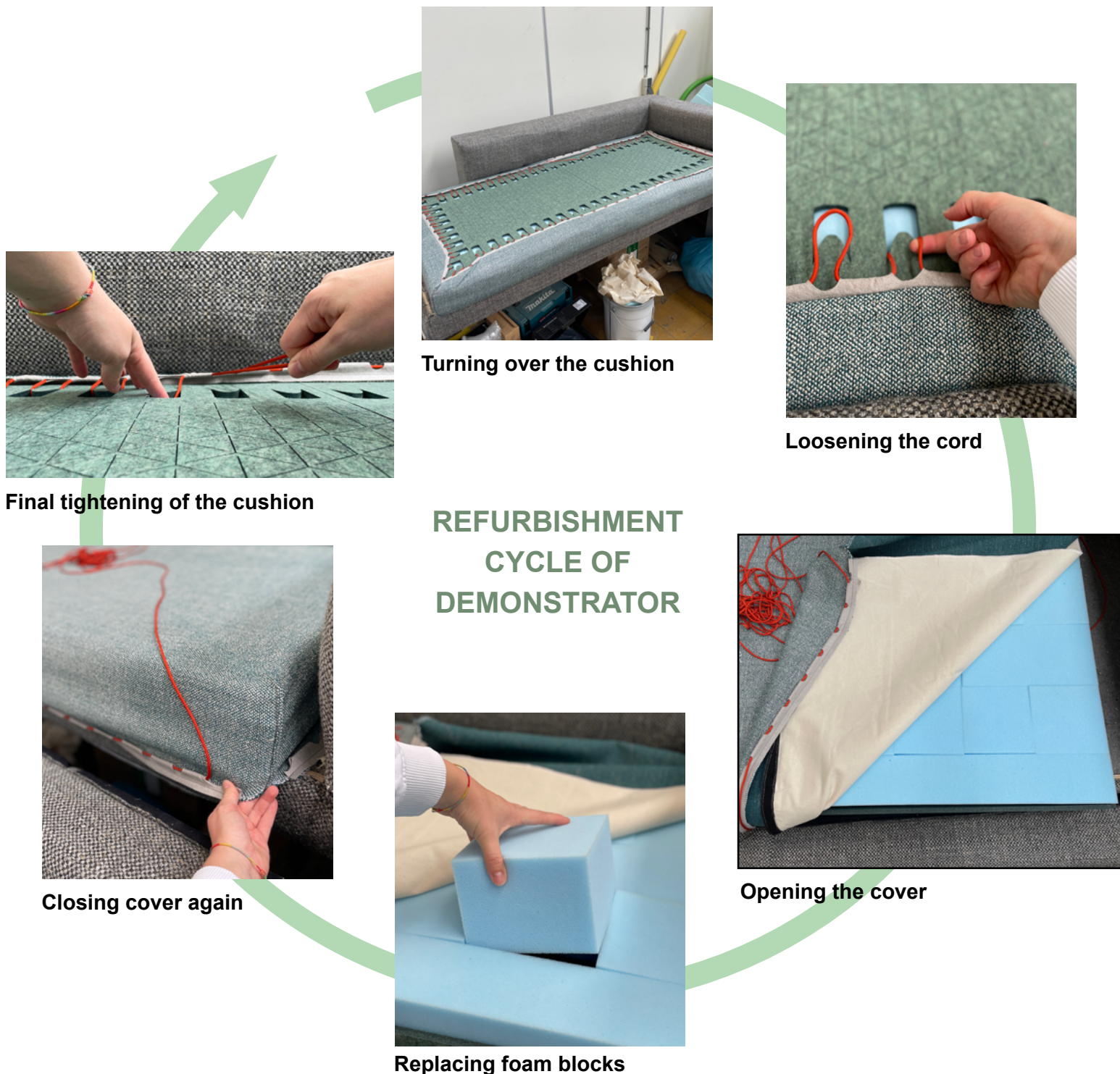
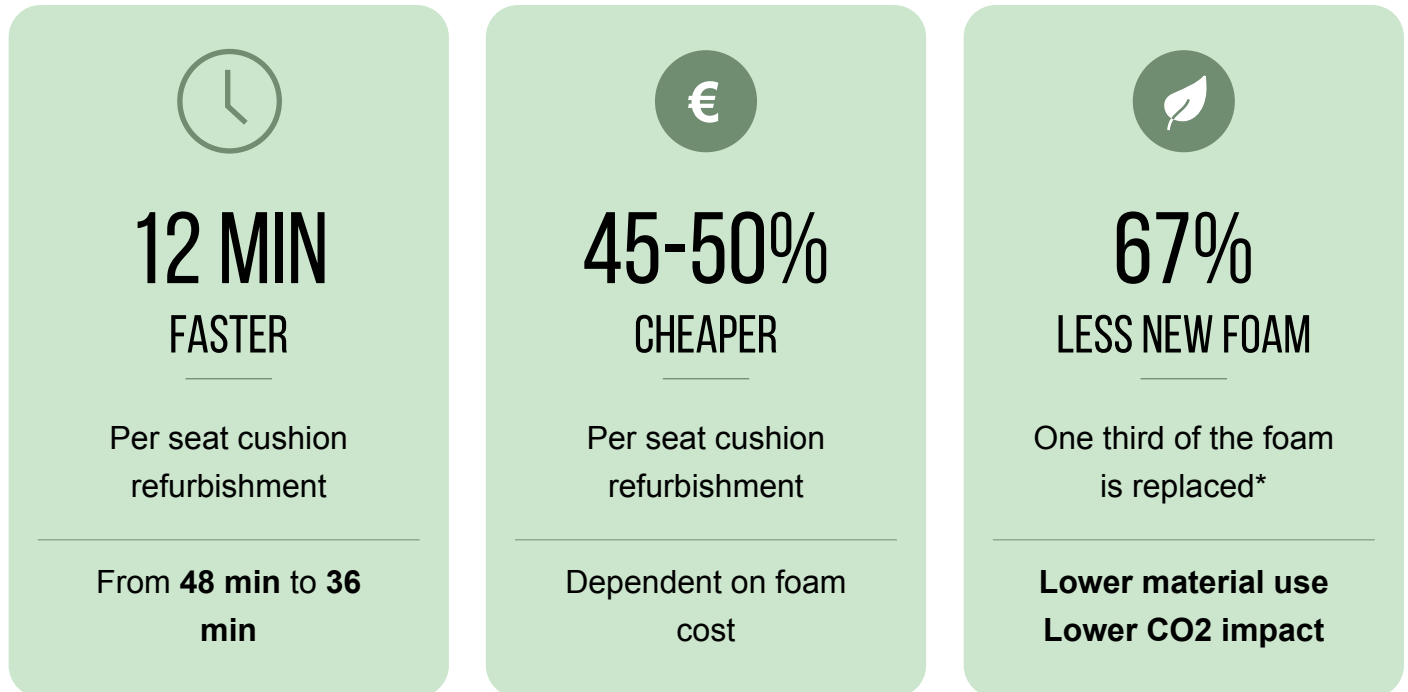


Figure 81: Refurbishment cycle of demonstrator

WHAT CHANGES DURING REFURBISHMENT?

Local block replacement reduces refurbishment time, cost and foam use per seat cushion.



Current refurbishment steps		New refurbishment steps	
Loosen cushion from couch:	6 min	Loosen pullcord:	5 min
Remove foam from cover:	1 min	Pull back cotton flap:	3 min
Saw new foam:	6 min	Replace sagged blocks:	5 min
Glue new foam:	20 min	Reupholster new cushion:	15 min
Reupholster new cushion:	15 min	Tighten pullcord:	8 min
Costs new foam plate:	€40 - €80	1/3 of new foam blocks:	€13 to €26
Total:	48 min	Total:	36 min
Costs:	€89 - €129	Costs:	€49 - €62

Key takeaway: the main benefit is material saving.

*For this calculation, one local sitting pit was estimated at 60 x 60 cm, a practical approximation of a generous single seating area. On a 180 x 80 cm cushion, this corresponds to a 4 x 4 block area. With a total of 48 blocks, replacing 16 blocks equals approximately one third of the cushion foam.

Figure 82: Changes during refurbishment

WHAT CHANGES DURING PRODUCTION?

The new cushion construction increases production cost, but improves foam recoverability after use.



0 MIN

FASTER OR SLOWER

Per seat cushion
production

Current estimate:
41 min in both cases



+€100

PRODUCTION COSTS

Per seat cushion
production

Mainly caused by **felt
plate inlay** and **pullcord**



NO GLUE

BETTER RECOVERY

Foam is easier to recycle

No staples in fabric
Reversible opening&closing

Current production steps

Saw foam:	6 min
Glue foam:	20 min
Upholster cushion:	15 min
Costs foam plate:	€40 - €80

Total: 41 min
Costs: €81 - €121

New production steps

Saw foam blocks:	10 min
Place blocks in inlay:	5 min
Mount cotton flap:	3 min
Upholster cushion:	15 min
Tighten pullcord:	8 min
Costs foam plate:	€40 - €80
Costs felt inlay:	€85
Costs pullcord:	€15

Total: 41 min
Costs: €181 - €221

Key takeaway: the design does not save time in first production yet. Its main value is creating a cushion that can be opened again later and repaired with less material

Figure 83: Changes during production

20.7 Refurbishment and production comparison

Figure 82 and Figure 83 show that the concept mainly creates value during refurbishment, not during first production. For one seat cushion refurbishment, local foam replacement can reduce the process from 48 to 36 minutes, while lowering costs by approximately 45 to 50 percent. The largest benefit is the reduction in new foam use: when only the worn sitting area is replaced, around 67 percent less new foam is needed compared to replacing the full cushion.

During production, the concept does not yet save time. *Figure 83* shows that the estimated production time remains around 41 minutes in both cases, while production costs increase by approximately 100 euros. This increase is mainly caused by the felt inlay and pullcord system used in the demonstrator. The main production benefit is therefore not cost reduction, but improved recoverability: no glue is needed between the foam parts, making the foam easier to separate, replace and recycle later.

Overall, the figures show a clear trade off. The current design asks for a higher investment during first production, but creates a cushion that can be opened again and repaired with less time, lower cost and less new material. The concept becomes most valuable when the couch is used over multiple lifecycles, rather than judged only on initial production cost.

20.8 Break even

With the current demonstrator assumptions, the additional production cost is approximately €100 per seat cushion. During refurbishment, the concept saves approximately €40 to €67 per cushion compared to replacing the full foam plate. This means the added production cost would be financially recovered after roughly two to three

refurbishment cycles.

This break even point should be read as an indication, since it depends strongly on the chosen inlay material, foam price and labour time. If the felt inlay or pullcord system can be simplified, the break even point could be reached earlier. If the couch is only refurbished once, the main value is not full financial recovery, but reduced foam use, easier access and better material separation.

20.9 Climate impact comparison

To evaluate the potential climate benefit of the final design, an indicative comparison was made between a linear replacement scenario and a refurbishment scenario enabled by the redesign.

In the current linear scenario, a new couch configuration is produced for each life cycle and the previous couch is sent to end of life incineration. In the redesigned scenario, the same base assembly is kept in use over three life cycles. The base assembly includes the wooden frame parts, nosag springs, metal feet and other structural components that remain functional during refurbishment. This means that two new base assemblies are avoided. *Table 3* shows the indicative avoided climate impact for two refurbishment scenarios. The first scenario assumes one additional life cycle, while the second scenario assumes that the couch remains in use for two additional life cycles.

The avoided material impact of the reused base assembly was calculated by multiplying the weight of each component by its material carbon footprint factor from the fast track LCA. This results in an estimated material impact of 89.92 kg CO₂-eq for one base assembly of the reference product. Over three life cycles, two new base assemblies are avoided:

$$2 \times 89.92 = 179.85 \text{ kg CO}_2\text{-eq avoided}$$

The foam compartment design also makes it possible to replace foam more selectively. The full foam set has an estimated material impact of:

$$17.12 \times 3.041 = 52.06 \text{ kg CO}_2\text{-eq}$$

For this calculation, it is assumed that two thirds of the foam can be reused for one additional life cycle, while one third is replaced. The avoided foam impact is therefore:

$$2/3 \times 52.06 = 34.71 \text{ kg CO}_2\text{-eq avoided}$$

In addition, the redesigned scenario prevents the couch from being discarded after the first and second life cycle. The final end of life moment is not eliminated, but delayed until after the third life cycle. The end of life incineration impact of the reference product is estimated at 99.09 kg CO₂-eq. Avoiding two incineration moments results in:

$$2 \times 99.09 = 198.18 \text{ kg CO}_2\text{-eq avoided}$$

The total indicative avoided climate impact is therefore:

$$179.85 + 69.42 + 198.18 = 447.45 \text{ kg CO}_2\text{-eq avoided}$$

This means that the final design could avoid approximately **447 kg CO₂-eq** for two Aikon

Lounge '13 right modules over three life cycles, compared to a linear scenario in which a new couch is produced and incinerated each cycle. The largest part of the saving comes from keeping the couch out of the waste stream for longer. Reusing the base assembly also has a large effect, because heavy and impact intensive components such as the metal feet, nosag springs and wooden frame parts do not need to be produced again. The foam saving is smaller than the avoided base assembly and incineration impact, but it is still important for the design strategy. Foam is one of the first components to lose function, and the compartment based design changes the refurbishment logic from full foam replacement to local replacement.

This comparison has several limitations. It focuses on avoided material production and avoided incineration. Transport back to the factory, inspection, cleaning, labour, new upholstery, Dacron, added fastening materials and detailed refurbishment processes are not included. These aspects should be added in a full LCA. The calculation is therefore mainly useful to show the direction and order of magnitude of the potential climate benefit.

Source of avoided impact per lifecycle	2 life cycles	3 life cycles
Reused base assembly	89,92 kg CO ₂ -eq	179,85 kg CO ₂ -eq
Selective foam replacement, 2/3 reused per additional lifecycle	34,71 kg CO ₂ -eq	69,42 kg CO ₂ -eq
Avoided incineration	99,09 kg CO ₂ -eq	198,18 kg CO ₂ -eq
Total avoided environmental impact	± 224 kg CO₂-eq	± 447 kg CO₂-eq

Table 3: Avoided environmental impact per lifecycle

20.10 Reflection on requirements

The list of requirements was used as a design target during the development of the demonstrator. Due to the limited time available at the end of the project, the final demonstrator was not fully tested against all requirements. The requirements should therefore be read as a framework for further validation, rather than as a complete proof that the final design meets every target.

Some requirements could be evaluated during the prototype tests. The foam compartment principle showed that individual foam parts can be removed and reinstalled, and that local replacement is technically understandable. The demonstrator also showed that the upholstery can be opened and closed without destructive removal of staples in the tested setup.

Other requirements were only partly evaluated. Comfort, seam visibility, block movement and ease of assembly were assessed during short term sitting tests, but not over longer use periods. The demonstrator therefore gives an indication of feasibility, but does not yet prove long term durability or user comfort.

The requirements related to production time, refurbishment time and climate impact were evaluated through estimates and an indicative climate impact comparison. These results suggest that the concept can reduce material use and avoid climate impact when the couch is used over multiple life cycles, but a full validation would require more detailed testing with DQG, including production trials, cost calculations and a full LCA.

For this reason, further validation of the requirements is included in the recommendations. The next development step should test the demonstrator inside an actual couch frame and evaluate it against the full list of requirements.

21. MANUFACTURING THE DEMONSTRATOR

21.1 Fabric cover design

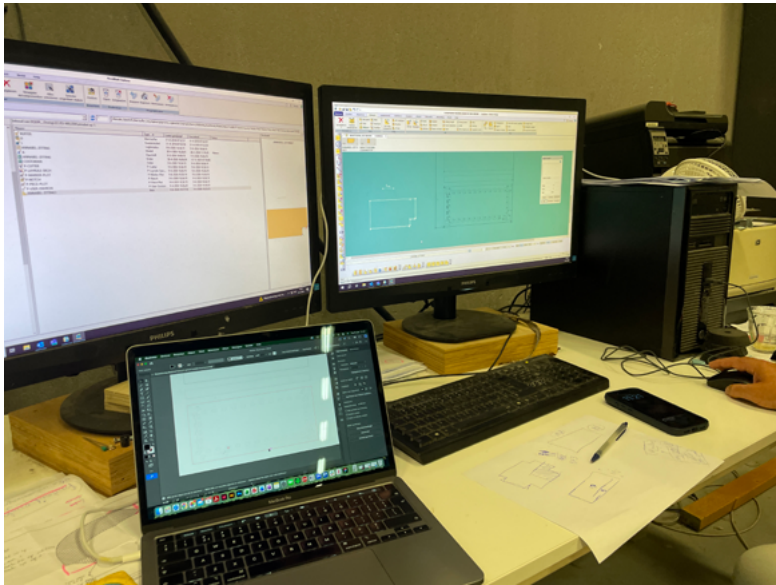


Figure 84: Turning my drawing into a usable sketch

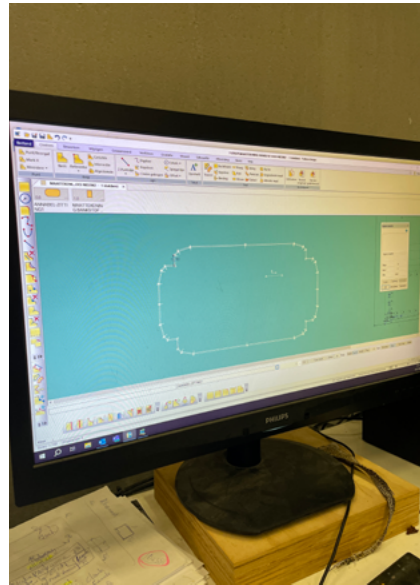


Figure 85: The sketch to use for cutting

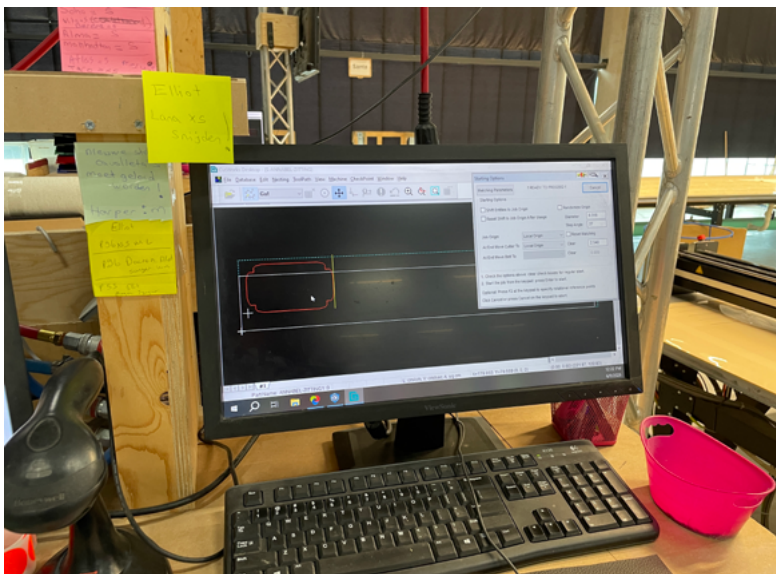


Figure 86: Uploading the sketch in software of cutting machine



Figure 87: Willem at the computer



Figure 88: Preparing cutting

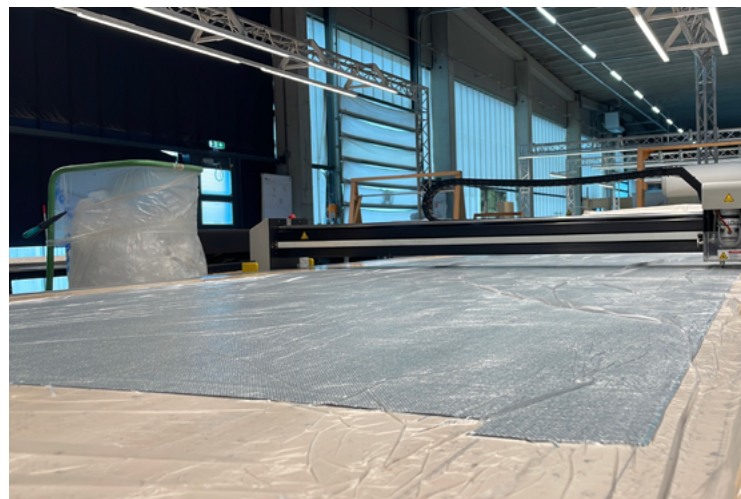


Figure 89: The machine while cutting

First I created a detailed drawing of how I wanted the fabric to look, which is displayed in *Appendix P-J* (see *Figure 84*). With the help of Willem Teurlings, a furniture maker and upholsterer at DQG, we turned my drawing into a sketch that could be used to cut the fabric on the cutting machines (see *Figure 85*, *Figure 86*, *Figure 87*, *Figure 88* and *Figure 89*). Afterwards, the cut fabric was overlapped and stitched by the sewing department.

21.2 Felt plate design

The design of the felt inlay consists of three things:

1. the anchor for the pullcord;
2. the pattern to make the plate more flexible;
3. the sides that stay upright without use of permanent fastening methods.

21.2.1 Pullcord anchor

First, a few designs were sketched (see *Figure 90*).

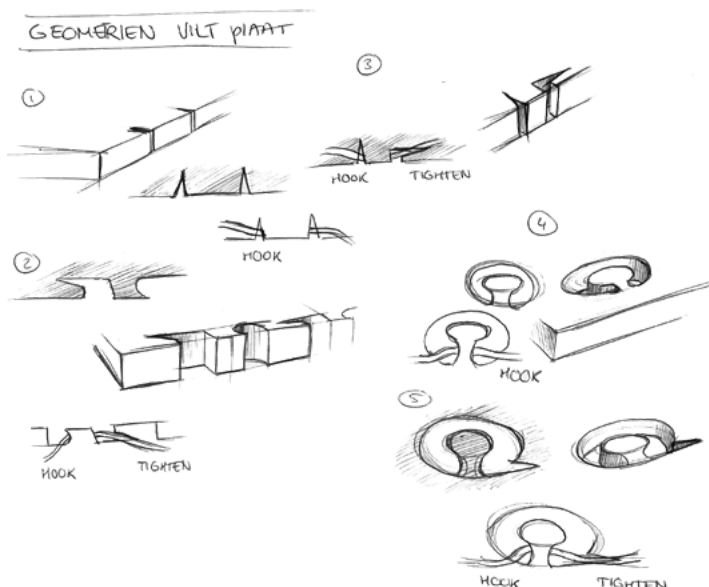


Figure 90: Sketches of anchor geometries

Geometry 1, 3 and 5 and two other options (building on geometry 5) were modeled and 3D printed to test the pullcord's behavior (see *Figure 91*). Geometry 5 was the best design in ease of mounting the paracord and freedom of location on the plate.

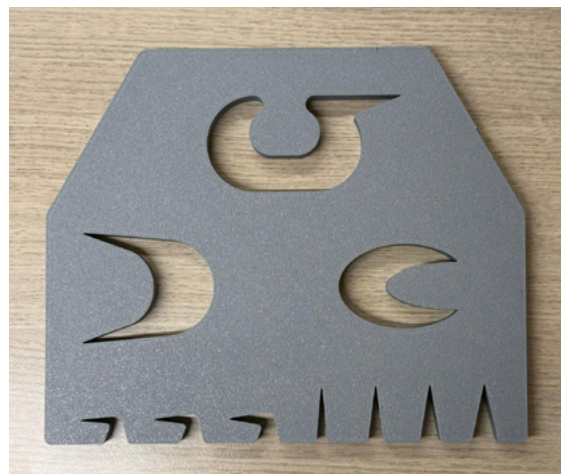


Figure 91: 3D print of geometries

The felt plate is less rigid than a 3D print. So I lasercut the chosen design, with several thicknesses of the notch to test the clamping of the paracord (see *Figure 92*).



Figure 92: Geometry 5 with different notch sizes

What appeared was that the bridge of the mushroom-shaped peg was too small and that the notch made it less stiff, it was prone to buckle. The size of the outer oblong was also too big. Additionally, I wanted to be able to clamp the paracord on both sides of the peg. So a redesign was made, based on the 3D printed design on the left (see *Figure 93*).



Figure 93: Redesign of anchor, different sizes to test stiffness

This design was stiffer, less likely to buckle, smaller and had the notch on both sides. The outer right design was chosen.

21.2.2 Pattern for flexibility

Next, patterns were developed to make the plate more flexible. Online research showed the following inspiration (see Figure 94).



Figure 94: Inspiration flexibility pattern (<https://nl.pinterest.com/pin/726064771216852921/> (left) and <https://nl.pinterest.com/pin/1147573548819315538/>) (right)

Designs were made from these patterns. Parts of the felt plate were lasercut and tested for flexibility in both the X and Y direction (see Figure 95).

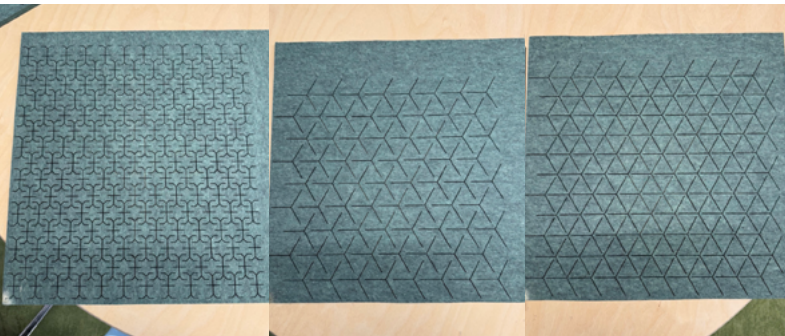


Figure 95: Three lasercut patterns (from left to right: H-shape, triangle shape (bridge 10 mm), triangle shape (bridge 5mm))

The conclusion from this test was that the right design, triangle shape bridge 5mm was the most flexible under compression. The H-shape design was more flexible in one direction than the other and the triangle shape with the larger bridge was too stiff. Playing with the bridge length will influence the flexibility of the plate. After loading, the plate returns to its flat shape. Since there is no information about the fatigue of the material, more research could be done to explore the possibilities of this material for this application.

21.2.3 The sides of the plate

The sides needed to be able to bend but not break, and stay upright and attached in the corners, preferably without using permanent fastening methods.



Figure 96: Inspiration side attachment (<https://nl.pinterest.com/pin/726064771216853360/>)

A nick in the plate made it possible to bend it but not break it. Setting the lasercutter to 15% force and 15 speed, made sure the laser did not penetrate the plate. The first design for the sides was inspired by the following design (see Figure 96).

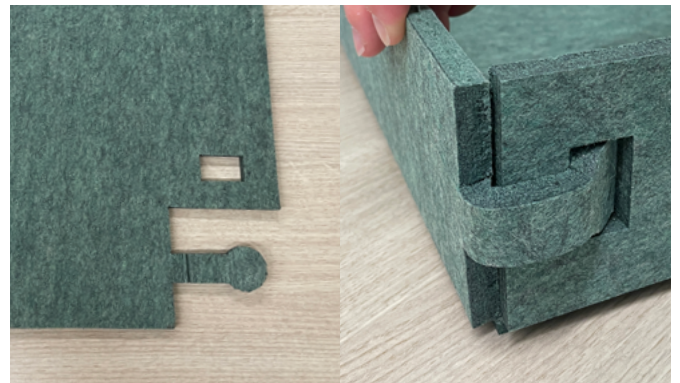


Figure 97: First design of the side attachment

This design worked well and the sides stayed together. However, the band of felt was visible under the upholstery, which was not desirable. Therefore, a new design was made (see Figure 98).

This design works only when the male side of the geometry is slightly bigger than the female side (1mm on both sides). However, for reliable interlocking the geometry needs to be further developed.

MANUFACTURING THE DEMONSTRATOR

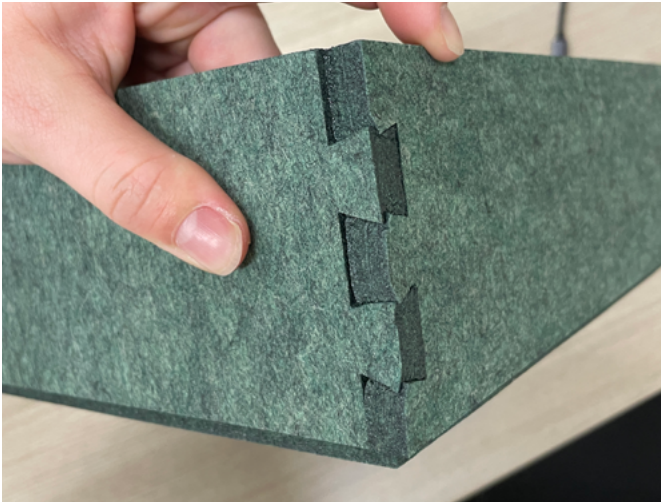


Figure 98: Interlocking side design

The entire felt plate needed to be lasercut. For this project a lasercutter with a 1 m by 1 m cutting bed was used, which meant the plate needed to be lasercut in two sections. One side of the plate was modeled, lasercut and flipped. For the future, a larger laser cutter is recommended, to prevent alignment discrepancies between the two sections.



Figure 99: Lasercutting the felt plate, the second half

22. WHAT DOES THE MARKET THINK?

In order to review whether the pullcord and foam compartments concepts are considered valuable for the market, a session was organised with other market players (see *Figure 100*).

The session was held with the following stakeholders:

- | | |
|----------------------|-----------|
| 1. Arnoud Vlieger | Ahrend |
| 2. Robert Heesakkers | Ahrend |
| 3. Frank Bouwma | Vepa |
| 4. Rudy Ghubpen | Vepa |
| 5. Ron Gubbels | Het Anker |
| 6. Marijke de Roo | Flokk |
| 7. Luc Gosselink | DQG |
| 8. Martijn ten Kate | The Bin |

22.1 Conclusions from the session:

B2B players are already further advanced in refurbishment and design for disassembly.

For B2B companies, design for disassembly is not necessarily new. Several parties already work on circular product development internally, meaning the concepts are valuable as inspiration, but less as a complete breakthrough.

“De ontwerp uitdaging is al daar. Daar zijn opties voor en daar lopen allerlei dingen voor.”

Frank, 00:51:35

For B2B, the biggest shared problem is the foam material itself.

The B2B participants mainly pointed towards the material challenge. They are looking for a sustainable foam alternative that can match current comfort, quality and price, while also being scalable and reproducible.

“Ik denk zelf een goede alternatief voor koud schuim, polyether schuim, dat duurzaam is.”

Arnoud, 00:49:49

For B2C players, my solutions are more interesting.

For B2C producers, the value of the project lies more in making refurbishment possible in the first place. Before foam can be replaced or reused, products need to become traceable, openable and easier to refurbish.

“Wij hebben besloten om echt te focussen op het design en die traceerbaarheid überhaupt van onze meubels. Dus wij zitten nog in het voortraject om dat allemaal überhaupt, het refurbishment voor ons of voor derden makkelijker te maken.”

Ron, 00:56:45

The pullcord concept is technically validated as a realistic principle.

The pullcord concept was not seen as unrealistic. A similar tensioning logic is already used in office furniture, which supports the technical feasibility of the principle. The added value of my concept lies in translating this logic towards couches and soft seating.

“Wij gebruiken al sinds 2010 in onze bureaustoelen althans geen lijm en geen boutjes meer en werken daarbij ook met een opspanningssysteem, min of meer gelijk zoals jij dat liet zien.”

“Je slaat dus eigenlijk de spijker op zijn kop”.

Marijke, 00:54:34

The concepts should not be sold as sustainability alone.

The market response suggests that circularity is not always a strong enough selling argument. The concepts become more interesting when they create direct value, such as better service, longer comfort life, easier repair or lower refurbishment cost.

“Het is leuk, het is mooi, alleen het is niet bepaalde toegevoegde waarde voor de consument in dit geval.”

Ron, 00:58:01

WHAT DOES THE MARKET THINK?

The strongest application is high quality B2C furniture with enough residual value.

The concepts are most relevant for products where the frame, suspension and brand value are still worth saving after the foam or textile has worn out. In that context, quicker access to wear parts can make producer led refurbishment more feasible.

The solutions are less relevant for very cheap furniture.

For low cost furniture, the additional production cost of modularity or reversible assembly is harder to justify.

“Als je een goedkoop stuk polyether één blok hebt, zakt het snel door en heb je een korte levensduur. Ga je met een gelaagde schuimlaag van verschillende kwaliteiten, dichtheden... dan zie je dat dus ook gelijk terug in de prijs.”

Arnoud, 00:48:02



Figure 100: Review session with stakeholders online

The solutions are also harder to apply to very complex, sculptural couches.

The concepts are easier to apply to simple rectangular soft seating than to highly shaped, double curved or hand upholstered furniture. In those cases, traditional upholstery techniques and glue may still be needed to achieve the desired form.

“Als ik denk aan Artifort met hele mooie dubbelgekromde oppervlaktes met veel handwerk... dan weet ik niet of je dat kan zonder lijm.”

Arnoud, 00:46:49

The main conclusion is not that every producer needs these exact concepts.

The session does not show that every producer needs these exact concepts, but it does show that future couch design should make wear components easier to access, remove, replace and trace.

23. APPLICATION IN A FUTURE REFURBISHMENT FLOW

The final demonstrator is not a production ready cushion, but a test object that Dutch Quality Group can use to evaluate how refurbishment could become part of future couch development. Its value lies in making the couch's hidden construction visible and tangible for discussion.

23.1 Testing refurbishment steps

The demonstrator can be used to test the practical steps of refurbishment with DQG employees. This includes opening the cushion, accessing the foam, removing a local foam section, placing new foam and closing the cushion again.

By performing these steps with upholsterers, product developers and production workers, DQG can evaluate whether the concept fits their existing way of working. The most important questions are: how intuitive the process is, where time is lost, which actions feel difficult, and which parts of the construction need to be simplified.

23.2 Evaluating production feasibility

The demonstrator also makes it possible to evaluate the production side of the concept. The current version is too complex to copy directly into production, so DQG should use it to identify which parts of the principle can be simplified.

Instead, DQG can use the demonstrator to identify which parts of the principle are valuable and which parts are too complex. The next design step should focus on reducing production cost, simplifying the inlay and testing whether the same access and positioning principles can be achieved with fewer or cheaper components.

23.3 Comparing refurbishment value

The demonstrator can help DQG compare two refurbishment routes: replacing a complete foam cushion, or replacing only the worn part. This comparison is useful because it makes the trade

off between production effort and refurbishment value visible.

For DQG, this does not mean that every product should be redesigned in the same way. The concept is most relevant for high quality couches with a high residual value, where the frame, brand value and production quality are still worth preserving. The demonstrator can therefore help DQG identify which products in the collection are most suitable for refurbishment oriented redesign.

23.4 Using the demonstrator in product development

The demonstrator gives DQG a physical object to test, discuss and improve. It can be used in internal evaluation sessions, conversations with upholsterers, discussions with foam suppliers and future product development meetings.

For DQG, the demonstrator can translate the general principle of accessible wear components into concrete product decisions: which cushion parts should open, which connections can be reversible, and which product models are suitable for refurbishment oriented redesign.

The main outcome is not that this exact cushion construction should be implemented. The main outcome is that DQG can use the demonstrator as a decision making tool. It helps test which refurbishment principles are worth developing further and which parts need to become simpler before implementation becomes realistic.

24. CONCLUSION

This project investigated how the design of upholstered couches can support repair and refurbishment instead of early disposal. The research showed that the main barriers are not only located at the end of life stage, but already built into the product architecture. Foam and upholstery are the parts that are most likely to wear out, but they are also difficult to access, remove and replace because of glue, staples, fabric tension and unclear disassembly sequences.

The context analysis showed that refurbishment only becomes realistic when product design, production logic and system conditions work together. Interviews with stakeholders confirmed that circularity alone is not enough to make a solution viable. Refurbishment has to be practical, economically relevant and technically feasible for producers and refurbishers. For Dutch Quality Group, this means that a redesigned couch should not only reduce waste, but also fit existing production knowledge and create value through quality, service and longer use.

The final design responds to this challenge through two design principles. The first principle is selective foam replacement. By dividing the cushion into foam compartments, worn areas can be replaced locally instead of replacing the full cushion. The second principle is reversible upholstery tensioning. By using a pullcord based system, the cover can be opened and retensioned without relying on permanent staples in the same way as the current construction. Together, these principles separate long lasting parts from parts that are more likely to wear out.

The demonstrator shows that this direction is technically possible, but also that further development is needed. The foam compartment concept can make replacement more local, but

the block positioning, comfort, seam visibility and production method still need to be refined. The pullcord concept shows potential for reversible upholstery, but needs further testing in relation to fabric tension, durability, cost and integration in a real couch frame.

The indicative climate impact comparison shows why lifetime extension is relevant. For two Aikon Lounge '13 right modules, the redesign could avoid approximately 224 kg CO₂-eq when the couch is used for two life cycles, and approximately 447 kg CO₂-eq when it is used for three life cycles. These avoided impacts come from reusing the base assembly, replacing foam more selectively and delaying end of life incineration. The calculation is not a full LCA, but it shows the order of magnitude of the potential climate benefit.

The main value of the design is therefore not that it makes replacement easier in itself. The value lies in making it possible to replace only what has actually lost function, while keeping the rest of the couch in use. This changes the logic of refurbishment from full replacement towards targeted intervention. For producers, this can make take back and refurbishment more feasible. For ReUse Alliance, the project shows how product design can support the wider system goal of keeping furniture out of the waste stream for longer.

The project concludes that circular couch design should focus on accessible wear components, reversible connections and product architectures that support multiple use cycles. The proposed design is not yet a production ready solution, but it demonstrates a realistic direction for reducing material loss and extending the usable life of upholstered furniture.

25. RECOMMENDATIONS

This project shows that couch refurbishment can be supported through product design, but also that the final demonstrator is not yet production ready. The following recommendations focus on what should be developed next, both at product level and system level.

25.1 Recommendations for the demonstrator

The next step is to further develop the demonstrator from a proof of principle into a more realistic test cushion. The current version shows that local foam replacement and reversible upholstery access are technically understandable, but several details still need improvement.

The next prototype should be tested against the full list of requirements. In this project, the requirements were used mainly as design targets, while only part of them could be evaluated through short term prototype tests. A next test should measure comfort, seam visibility, foam block displacement, assembly time, replacement time, production time and structural stability in a more realistic couch setup. This would make it possible to determine which requirements are already met and which need further development.

First, the comfort of the cushion should be tested more thoroughly. The current test mainly evaluated short term block movement and seam visibility. A next prototype should be tested with multiple users, longer sitting periods and repeated loading over time. Specific attention should be paid to the front edge of the cushion, because a hard edge underneath the legs could reduce sitting comfort.

Second, the inlay should be simplified. The current felt inlay helps position the foam blocks, but it adds material, production cost and laser cutting time. Alternative solutions should be tested, such as a textile sleeve, a simpler felt strip system, a wooden positioning frame or a cheaper flexible

support layer. The goal should be to keep the blocks in place without making first production too expensive.

Third, the pullcord system should be developed further with upholsterers. The principle works, but the visual finish, cord wear, tension distribution and ease of tightening need more testing. The cord system should reach the quality level expected in high end upholstered furniture.

Fourth, the demonstrator should be tested inside an actual couch frame. The current cushion demonstrates the principle as a separate object, but the next step should evaluate how it is fixed into the couch, how it interacts with the nosag springs and whether the cushion remains stable during daily use.

Finally, the next demonstrator should include a clearer validation plan. Each requirement should be linked to a specific test method, such as a timed replacement test, a repeated sitting test, a visual seam inspection, a comfort evaluation with users or a production trial with DQG. This would make the next prototype more useful as a decision making tool and would show which parts of the concept are ready for further development.

25.2 Recommendations for future couch design

Future couch designs should treat foam and upholstery as accessible wear components instead of permanent layers. This does not mean that every couch needs foam blocks or a pullcord system, but it does mean that the main wear parts should be easier to reach, inspect, remove and replace.

For upholstery, future designs should avoid placing zippers or fastening systems in high tension areas. Upholstery parts should also be separated

according to the component they cover. A seat cushion, backrest and frame should not depend on one continuous cover if this makes local refurbishment difficult.

For foam, future designs should avoid unnecessary glue, especially where foam may need to be replaced or separated later. If glue is still needed for comfort or shape, it should be applied in a way that does not contaminate large foam surfaces or prevent later separation.

Future designs should also make the disassembly sequence readable. Repairers, upholsterers or disassembly workers should be able to understand where to start, which parts can be opened and which connections are reversible.

25.3 Recommendations for Dutch Quality Group

As part of the final evaluation, Luc reflected on the value of the demonstrator for DQG:

Although Dutch Quality Group currently has no concrete plans to implement the developed concepts directly, he described the physical model as a valuable outcome of the graduation project. According to him, the model makes it visible in an accessible and tangible way how a couch seat could be designed differently in the future, with more attention to maintenance, replacement and circularity.

The modular structure of the seat is especially relevant in this context. The principle that individual foam blocks can be replaced instead of the complete seat cushion connects to the ambition to reduce material use and climate impact. The pullcord system for easier cover removal also offers relevant possibilities from a maintenance and repair perspective.

At the same time, Luc indicated that the concepts

do not yet directly fit DQG's current product development and production processes. This means that the demonstrator should not be treated as a ready to implement product design. Instead, it should be kept as a reference model for future development. The furniture industry is facing increasing pressure around sustainability, circularity and future regulation, including the further development of Extended Producer Responsibility for furniture. In that context, the principles explored in this project may become more relevant over time.

For that reason, DQG should preserve the model as a physical knowledge object. It captures the insights from this graduation project and can serve as an inspiration source and starting point for future ideas, follow up research and innovation projects within the organisation. Its main value is that it makes fundamental questions about circular furniture design tangible: which parts should last longer, which parts should be replaceable, and how can a couch be designed so that refurbishment becomes more realistic?

Based on this, the first practical recommendation for DQG is to identify which products in the current collection are most suitable for refurbishment oriented redesign. The concept is most relevant for high quality couches with a high residual value, where the frame, suspension and brand value are still worth preserving after the foam or upholstery wears out.

Second, DQG should analyse its existing products for circular design principles that are already present. Some current construction details may already support disassembly, replacement or refurbishment. Mapping these existing strengths can make circular product development more practical and less dependent on completely new concepts.

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Third, DQG should run a small refurbishment pilot with one selected couch model. This pilot should compare the current refurbishment process with an improved version focused on easier upholstery access, less foam glue and faster seat cushion replacement. The pilot should measure time, labour difficulty, material use, cost and quality of the final result.

Fourth, DQG should explore how refurbishment can be positioned as a premium service. For DQG's target group, circularity alone is unlikely to be the strongest selling argument. The value should be communicated through comfort life, quality, maintenance, service and the possibility to keep a high quality couch in use for longer.

25.4 What should ReUse Alliance do next?

The evaluation session with market players showed that the two design directions were received differently. The pullcord concept was recognised as a relevant and realistic direction, partly because Flokk indicated that they are already exploring similar principles. This gives the concept external validation: reversible fabric tensioning is not only interesting within the DQG case, but also connects to developments already happening in the market.

The foam block concept received less direct interest from the group. This does not mean that the concept has no value, but it does suggest that it should not become the central shared solution for all furniture producers. The current concept is still specific, relatively costly and dependent on further testing of comfort, production time, inlay material, inspection and long term use. It is therefore more suitable as a design research direction than as a sector wide implementation route.

25.4.1 Moving from foam blocks to foam research

This fits the outcome of the evaluation session with the discussion with market players (see *Chapter 22*). In the presentation, five directions were presented: jointly purchasing bonded foam, more specific research into foam for the furniture industry, redesign to avoid glues, redesign for foam reuse, and interchangeable foam parts. During the stakeholder discussion, the strongest shared interest appeared to be in the second direction: better and more specific research into foam for the furniture industry.

For ReUse Alliance, this means that the next step should not be to organise a large shared pilot around foam blocks. Instead, ReUse Alliance should use the foam block demonstrator as an example of what product architecture can make possible: local replacement, less glue, cleaner separation and lower material use during refurbishment. The broader chain breakthrough should focus on the underlying foam question: which foam materials, constructions and processing routes can support repair, refurbishment and recycling in the furniture sector?

25.4.2 Return rate

An important condition is the expected return rate. ReUse Alliance estimates that around 15 percent of sold furniture may realistically return to the producer. This estimate is based on the current practice of Gelderland, where approximately 15 percent of sold furniture is already returned and refurbished. This number is a proof of concept for the scale that the current system can already reach.

The additional production cost is added to every couch, while refurbishment savings only appear for the smaller group that actually returns. With the current demonstrator assumptions, the concept adds approximately €127 per seat cushion in

production and saves approximately €36 to €43 per local refurbishment. At product level, this can become valuable when a returned couch is refurbished multiple times. At system level, it does not financially break even if only 15 percent of products return. The added cost is carried by the full product flow, while the saving is created by only a small share.

25.4.3 *What this means for design*

Calculated across the full flow, the current concept would need roughly 20 to 24 local refurbishments per returned cushion to recover the added production cost. This is not realistic for the current system. Refurbishment enabling features must therefore either be much cheaper, create value during first use, or be applied selectively to products with a high expected return value. The pullcord concept is stronger in this respect, because it uses less additional material and can also create value by making access, inspection and repair easier.

25.4.4 *Assignments for ReUse Alliance*

For the coming years, ReUse Alliance could focus on five assignments.

25.4.4.1 Coordinate furniture specific foam research

ReUse Alliance should bring together producers, foam suppliers, recyclers and knowledge institutes to investigate which foam types are suitable for future furniture applications. This research should not only compare environmental impact, but also comfort, durability, cost, availability, recyclability and compatibility with refurbishment.

The goal is to move beyond separate pilots by individual producers. Foam is a shared, non competitive challenge, and the sector would benefit from a shared knowledge base on material options, recycling routes and future requirements.

25.4.4.2 Define criteria for refurbishable foam

Next to material research, ReUse Alliance should translate product level insights from this project into shared criteria for refurbishable upholstered furniture. These criteria could include access time, separability of foam layers, avoidable glue use and contamination of foam streams after use.

The estimated 15 percent return rate should be included in these criteria. A refurbishment friendly design is only scalable when the added production cost stays low enough to be carried by the full product flow, or when the design creates value before the product returns.

These criteria should not prescribe one fixed solution. A B2B soft seating product, a high end B2C couch and a modular lounge system will need different constructions. The value lies in agreeing on what refurbishable foam should enable, not in forcing every producer to use the same construction.

25.4.4.3 Explore reversible upholstery access

The pullcord concept should be explored further as a low threshold product adaptation. It focuses on access: if upholstery can be opened and closed more easily, inspection, foam replacement and repair become more realistic.

This direction can be developed individually by producers, while ReUse Alliance collects and shares lessons on demountable upholstery, tensioning systems, fastening methods and production feasibility. The fact that a market player recognised similar developments makes this direction more directly relevant for short term experimentation.

25.4.4.4 Test disassembly halls as refurbishment hubs

ReUse Alliance should also explore a producer

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linked network with disassembly halls. In this future system, returned couches do not all need to go directly back to the original factory. Instead, disassembly halls could become regional preparation points where couches are identified, stripped and separated into usable components and material streams.

For a producer such as DQG, this could create value if the wooden frame can be recovered and returned to the factory. The frame represents a large part of the couch, both in material volume and production effort. If a disassembly hall removes the upholstery, foam and contaminated layers, the producer could receive a cleaner frame that is ready for inspection, repair and re entry into the production or refurbishment flow. This could save material, production time and emissions compared to producing a completely new frame. In this model, the producer pays the disassembly hall for a defined preparation service. The main challenge is logistics. Transport costs can quickly become too high when individual couches are moved one by one over long distances. ReUse Alliance should therefore investigate regional batching, shared transport routes, product identification and agreements between producers, municipalities and disassembly halls.

25.4.4.5 Translate pilots into standards and UPV criteria

Lastly, ReUse Alliance should use the outcomes of foam research, product pilots and disassembly hall tests to influence future standards and UPV discussions. A formal NEN standard may be too early immediately, because the sector first needs evidence on what works. A better first step would be a guideline for refurbishable upholstered furniture.

This guideline could define what makes a couch refurbishment ready. For example: whether the

upholstery can be opened without damage, whether the seat foam can be removed separately, whether glued material combinations are avoided, and how long it takes to access the main wear components.

Over time, this could support NEN standard development or UPV fee differentiation. Products that are faster to refurbish or disassemble could then receive a lower processing burden than products that take hours to separate. This would make design for refurbishment financially visible, instead of leaving it as a voluntary sustainability ambition.

For ReUse Alliance, the assignment is not to select one final couch construction. The assignment is to build the shared knowledge, test infrastructure and policy conditions that allow producers to earn money from refurbishment and reuse.

25.5 Recommendations for further research

Further research should investigate the long term behaviour of compartment based foam cushions. The current tests show short term feasibility, but not long term comfort, block movement, seam visibility, material fatigue or user acceptance.

More research is also needed into the environmental trade off of adding extra components during production. The demonstrator reduces foam use during refurbishment, but the added inlay and pullcord system increase first production cost and material use. A full LCA over multiple lifecycles should be carried out to determine when the concept becomes environmentally beneficial.

Future research should also compare different furniture segments. The concepts are most relevant for high quality B2C couches with enough

residual value to justify refurbishment. They may be less relevant for very low cost furniture or highly sculptural couches where traditional upholstery techniques are needed.

Additionally, a next step is to perform a full LCA of the redesigned couch system. The current comparison is based on a fast track LCA and is useful to estimate the order of magnitude of the potential climate benefit. However, it only focuses on Global Warming Potential and does not yet include all impacts introduced by refurbishment. A full LCA should compare the current linear scenario with several refurbishment scenarios, including two and three life cycles. It should include transport back to the factory, inspection, cleaning, labour, replacement upholstery, Dacron, added fastening materials, foam replacement, production changes and end-of-life processing. The assessment should also include other impact categories besides kg CO₂-eq, such as resource depletion, toxicity, acidification, eutrophication, water use and land use.

This is important because the current calculation suggests that lifetime extension can avoid a large amount of climate impact, but it does not yet prove that the redesign performs better across all environmental categories. A more detailed LCA would make it possible to validate the environmental benefit of the concept, identify possible trade-offs and support future decision making by DQG or ReUse Alliance.

Finally, future research should explore the business model around producer led refurbishment. Product design can make refurbishment easier, but it only becomes realistic when return logistics, inspection, storage, labour and resale channels are organised as part of the system.

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Picture of me sitting on the demonstrator cushion on the frame of the Aikon Lounge '13

