

Towards a circular design approach for products made from locally collected waste

Expanding EcoWorld's product portfolio with meaningful design, for local Kenyan people, from collected plastic waste



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Special Thanks

Throughout my Master's at TU Delft, I always had a clear idea of my ideal graduation topic. I started scuba diving with my dad at age 12, and that's when my love for the ocean began. This passion led me to an interest in the underwater environment and its alarming degradation. So, when I found EcoWorld, a non-profit on Kenya's west coast that collects plastic from beaches and streets to clean the environment and kickstart a local recycling economy, I knew it was a perfect fit. After some back and forth, we came up with a project brief that suited both me and EcoWorld. Besides addressing the decline of the aquatic environment, the project also tapped into my interest in designing for emerging markets. There's a lot of potential for plastic recycling economies in developing countries, and I was eager to dive into the topic.

I was super excited to engage with the local end-users and couldn't wait to travel to Kenya. When Steve, EcoWorld's founder, mentioned, "It would be nice if you could even come here to do research, but I don't know if that is possible for you?" he had no idea how thrilled I was. I was so happy to get the chance to go straight to the local communities. It was a fantastic opportunity to get hands-on with the project and learn about facilitating creative sessions in a different culture. Talking to so many people and learning about designing for a different context and culture was incredibly valuable.

I want to thank Steve for all his help during this project and for making my stay in Watamu possible. Thanks for your enthusiasm during our meetings and my time in Watamu. Big thanks to the rest of the EcoWorld team: Hellen, Dennis, Karen, Irene, and Anne. I appreciate all your help during my stay, reaching out to community members, assisting with translations, and making me feel welcome. I'll never forget our day off touring the coastline.

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Thank you all, and enjoy reading!

Leander Hombergen

Glossary

Abbreviations

Term	Definition
Ksh	Kenyan Shilling (the local currency in Kenya)
CE	Circular Economy
PS	Polystyrene
PET	Polyethylene terephthalate
HDPE	High-density polyethylene
PP	Polypropylene
WMA	Watamu Marine Association
R-strategies	Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover
SME's	Small to medium enterprises
DIY	Do It Yourself

Executive Summary

This research project explores opportunities for EcoWorld to expand their product portfolio beyond mere recycling. The initial goal was to investigate potential products that could improve the living conditions of local communities in Watamu, Kenya, using collected plastic waste. EcoWorld, a local non-profit organization, aims to ignite the plastic recycling economy in Watamu by creating dynamic value waste streams and empowering women and youth as drivers of this economy. However, they face challenges in moving from recycling to circular design practices and in identifying suitable products for the local communities.

The research begins by defining the local context and identifying key stakeholders. It reveals a significant plastic waste problem in Watamu and inadequate living conditions for the local communities. While there is a growing understanding of the potential of collecting and recycling plastic waste, a knowledge gap hinders progress towards more circular practices. The research clarifies what circular practices mean in the local context, centering on creating products from plastic waste that offer enhanced social benefits to end-users while managing the entire lifecycle of these products. It explores EcoWorld's potential to build a business around this approach and develops a framework for integrating circular practices into local product production. Integrating local end-users into the design process emerged as a key opportunity to create value, understanding, and awareness, ensuring proper waste management and slowing down the resource loop.

A four-week field research in Watamu engaged these various stakeholders in the design process. Observations and interviews with EcoWorld employees highlighted the potential for new technologies to move beyond recycling and the openness to raising community awareness. Creative sessions with local communities provided insights into their perspectives on plastic pollution and their needs for improving their living conditions. While there was interest in using plastic waste materials, trust in these materials for structural improvements, like bricks for houses, was lacking. However, there was significant interest in improving household cleanliness through storage solutions.

Based on these insights, a cabinet design was developed during the design phase together with the local end users. The design focuses on practicality and simplicity to fit the local market, emphasizing functionality and ease of use. The production process was kept simple with minimal tool requirements to ensure feasibility for local production at EcoWorld. The design aligns with the established circular framework, ensuring proper handling of the product at its end-of-life, thereby slowing down the resource loop.

Finally, a transition model was created for EcoWorld's future growth. An implementation plan for the current product includes the necessary tools and machines for successful production. The transition model is based on building trust among end-users as they become familiar with using plastic waste materials for products and actively participate in the emerging economy. This involvement will enable EcoWorld to expand their product portfolio further and focus on proper waste management in the future, creating jobs and income for women and youth in Watamu, igniting the local plastic recycling economy.

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Reading Guide

This reading guide is made to increase the understanding of the structure of the report to the reader. Each chapter is color-coded to help readers easily identify different chapters. Every chapter starts with a brief introduction outlining its content. At the introduction, a visual representation of the design process indicates where the reader is within the overall project. Prior to design focus chapter, key takeaways are found. These key takeaways are summarized at the end of each chapter and lead to specific design requirements, listed below them. These key takeaways and design requirements are revisited in the design focus chapter, where they are clustered towards actionable points that lead to a design goal to start the design phase.

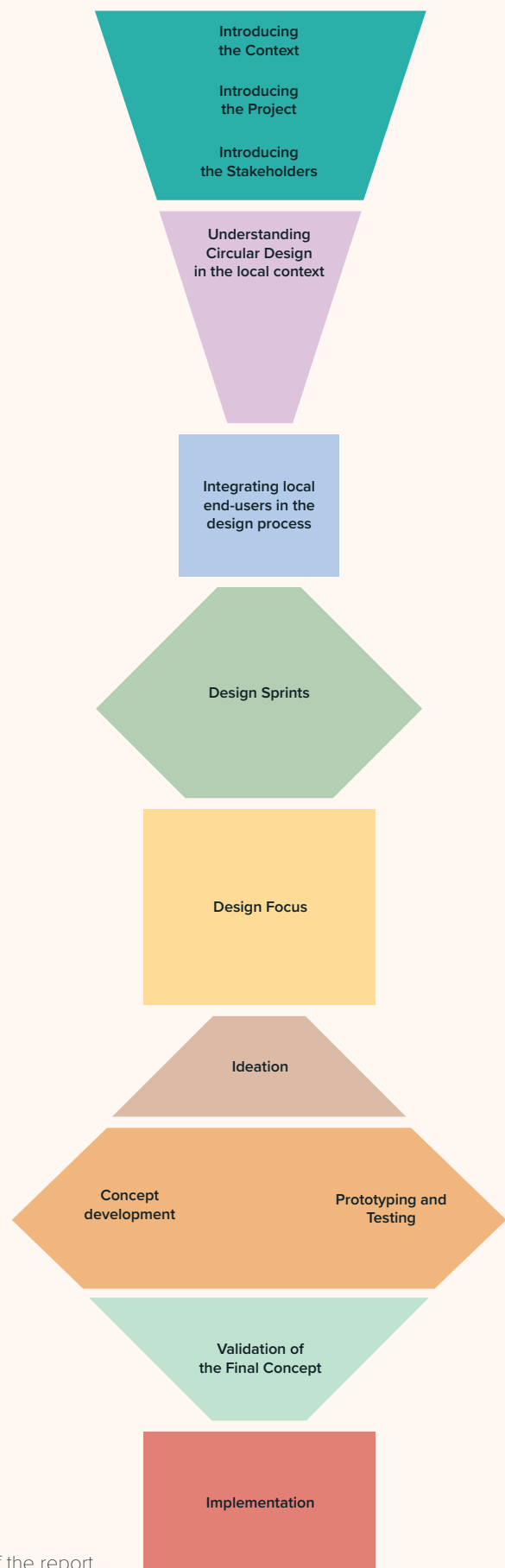


Figure 1: Color coded structure of the report

2.5 Key Takeaways and Design Requirements

Key takeaways from co-creation

- 2.1 The co-creation method should be used to achieve a social value impact which leads to higher consumer satisfaction.
- 2.2 Co-creation sessions should be generative to understand a deeper level of experiences.
- 2.3 The cultural dimensions of the Kenyan culture need to be research in preparation of the field research.
- 2.4 In preparation of, and during the sessions, a cultural translator is imperative to design culturally appropriate sessions and understand the nuances during the research activities.
- 2.5 The creative sessions should be designed for cultural appropriateness to achieve a greater acceptance and satisfaction amongst the end users.
- 2.6 Using the 'bottom-up approach' will help ensure that solutions are tailored to the specific context and empower to take ownership of the outcomes.
- 2.7 The design process should involve the end users to built effective and long lasting loyalty.

From the key takeaways the design requirements are defined

Design requirements

Involve end-users in the design process to encourage satisfaction and long-lasting solutions
Design should be made and understood by local workers for better implementation



Visualization of where the reader is in the design process

Figure 2: Example pages on the structure of the report

01

Initiating the Project

This chapter introduces the project by outlining the context, the problem areas and the stakeholders involved in the research.

The initial problem definition and project assignment are explained first. With this foundational understanding, the context is elaborated to delve into the specific problem areas. Next, the various stakeholders are introduced, narrowing down to the main purpose and goal of the research project. Finally, key takeaways are clustered, and a conclusion is drawn.

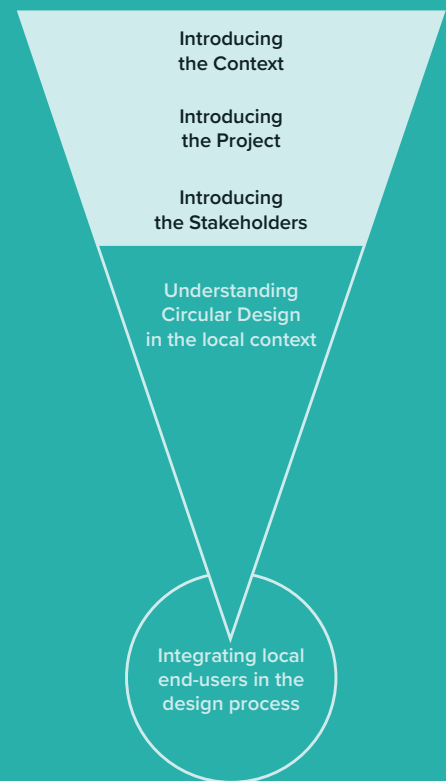




Figure 3: Collected PP waste at EcoWorld

Chapter Overview

- 1.1 Introduction
- 1.2 The Context
 - 1.2.1 Plastic Pollution in Kenya
 - 1.2.2 Watamu
 - 1.2.3 Housing Conditions
- 1.3 Introducing the project
 - 1.3.1 Problem Statements
- 1.4 The Stakeholders
 - 1.4.1 Stakeholder Map
 - 1.4.2 EcoWorld
 - 1.4.3 People of Watamu
- 1.5 The Research Aim
 - 1.5.1 The Purpose of this Project
- 1.6 Key Takeaways and Design Requirements
- 1.7 Conclusion

1.1 Introduction

This project is conducted in collaboration with EcoWorld, a plastic recycling company based in Watamu, Kenya. EcoWorld's initial challenge was the difficulty in integrating their prototype brick into the local market. Additionally, the company aims to expand its portfolio to create dynamic value waste streams along the Watamu coastline. However, they have not yet researched the end user's perspective and their needs in the local market. Therefore, this research project explores ways to produce products following a circular product life cycle approach and ways on how to implement a circular design approach in a developing country. Moreover, to expand the current product portfolio, a new product is developed from the end users' perspective by involving local communities in the design process.

The project assignment is to create a framework for shifting from mere recycling to an upcycling approach, producing products following a circular design methodology. The focus is on developing products that improve the living conditions of local households, in line with the scope of EcoWorld's brick prototype. Throughout the design process, end users are involved to ensure that their perspectives and cultural aspects are integrated into the design.



Figure 4: EcoWorld sign, outside their factory

1.2 The Context

Plastic pollution has become a widespread issue in recent years. Imagine yourself walking near your home, you are sure to spot plastic waste on streets, curbs, or in nature.

Annually, 350 million tonnes of this plastic waste is produced, with 6 million tonnes ending up in rivers or coastlines (OECD, 2022). Research by The Ocean Cleanup found that 80% of ocean plastic waste comes from 1,000 rivers worldwide, primarily situated in developing countries due to inadequate waste management and a lack of adequate infrastructure (Lourens, 2021). This section dives deep into the context of Watamu, explaining the current living environment as well as the housing status.

1.2.1 Plastic Pollution in Kenya

This project focuses on Kenya in East Africa, one of these developing countries. Rivers from Nairobi and other cities contribute significantly to ocean plastic pollution, increased by harsh climate conditions like heavy rainfall.

EcoWorld is a company that is exploring circular economy in Kenya. Kenya is a frontrunner in Africa in terms of development towards circular design, setting the first step towards their sustainability goals. In Africa there is a big need for this new emerging economy, while it brings a lot of job opportunities and skill and knowledge development. Circular behavior is already rooted in the African country and will be further explored in this report. This progressive mindset shows a big opportunity for EcoWorld while the local communities are eager to learn about this emerging economy, but lack the understanding of this topic as of yet.

Initiatives to collect plastic waste along Kenya's coastline have successfully cleaned beaches and fostered a new economy. However, there is currently no purpose for the collected waste. Youth in Kenya have shown growing concern about plastic pollution and are advocating for sustainable alternatives (Oguge et al., 2021). There is widespread support among the youth for initiatives promoting reusable alternatives, with a preference for enhanced awareness campaigns, improved waste infrastructure, or even a complete ban on single-use plastics.

Looking ahead, Kenya aims to further strengthen its position as a leader in plastic pollution reduction by considering alternatives to single-use plastics. Amos Wemanya, Senior Advisor on Just Energy Transition in Kenya, emphasizes the importance of companies transitioning away from plastic dependence in anticipation of a global plastic treaty (Heinrich Böll Stiftung, 2022). Kenya's commitment to addressing plastic pollution sets a precedent for other African nations and underscores the urgency of adopting sustainable practices to safeguard the environment for future generations.

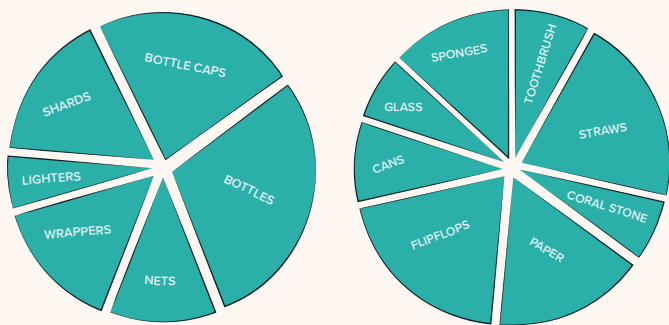


Figure 5: Plastic waste products found in Watamu

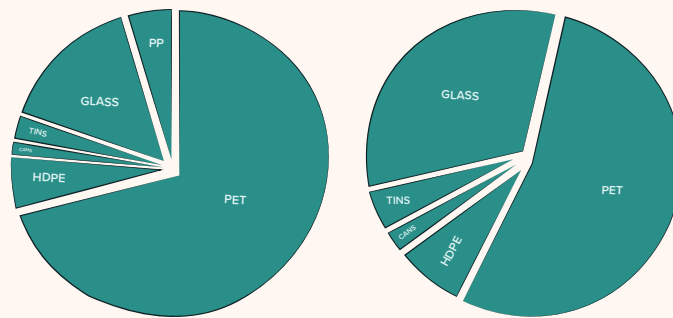


Figure 6: Types of plastic collected, and what is sold

1.2.2 Watamu

Watamu is a coastal village a little over 100 km above Mombasa in Kenya. Watamu is seen as a great tourist destination along the coast of Kenya, with its rich bio-diverse marine area. Along the coast, a National Marine Park and Reserve has been set up, which is now a protected conservation area. In this section, an overview will be given of the current living conditions in terms of the local economy, climate, environment, and housing status.

1.2.2.1 Economy

Watamu lies in the county of Kilifi. In Kilifi, the poverty rate lies at 49.2 percent of the total population in the county, which is amongst the highest in Kenya, with the overall poverty in the country being at 38 percent (KNSB, 2021). The Gini coefficient of Kilifi is also amongst the highest along the whole coastline sitting at 0.570 (SID, 2013). The Gini coefficient is a statistical measure to indicate the inequality of income in a country or area. It measures between 0 and 1, with 1 being total inequality, so the higher the number the more inequality (Hasell, 2023). In the past, agricultural labor used to make up for most of the labor force in Kenya. However, in recent years this has changed to the informal sector, which leads to poor employment prospects for the youth and especially women according to the Wonder Foundation (2020). Furthermore, women get paid significantly less than men in Kilifi, which only shows the importance of addressing this inequality.

1.2.2.1 Plastic waste in Watamu

In Watamu, a diverse range of trash is collected from beaches and streets, including items like flip-flops, straws, and nets. EcoWorld has illustrated this through two pie charts shown above (figure 5), giving an estimation of the relative quantity of each type of trash collected. The organization processes up to 10 tons of plastic waste per month, compensating informal collectors for approximately 10 ksh (7 eurocents) per kilogram. The fake market that emerges now, offers 50 ksh (35 eurocents) per kg to residents. This creates a big challenge for EcoWorld to compete and will be further explained in section 1.4.2.

Among the plastics received, PET, HDPE, and PP are the most prominent. While PET and HDPE have resale markets after recycling, PP lacks demand and piles up at the facility. This can be seen in the pie charts above (figure 6). The left chart shows the incoming plastics and the right one the sold plastics in their relative fashions. EcoWorld faces a knowledge gap regarding the utilization and value creation of this PP material that keeps piling up at the facility.

The current waste management system in Watamu, overseen by the government, is inadequate. Residents must pay for waste collection services, leading to environmental degradation and landfill overflow. Consequently, there is a pressing need for a more effective waste management system that prevents waste from ending up in the environment and landfills.

Climate

Watamu is located near the equator and therefore has a tropical climate. The temperature fluctuates between 24 and 31 degrees Celsius. Watamu is also known for its savannah-like climate but it does have Monsoons which result in very harsh weather conditions. That is why the local community needs to have adequate housing for these conditions, and unfortunately, that is not the case at the moment. These Monsoons hit from April to July, and during this time the current of the ocean switches land inward. This means that with this heavy rain, a lot of plastic waste ends up in the rivers, which lead to the oceans where it is pushed directly back on the beaches of Watamu. According to Steve, the director of Watamu, these months you can clean the beach each day, but it would not matter. This litter comes from Nairobi and is mostly from Kenyan residents.



Figure 7: Scenic photo of the environment with plastic waste



Figure 8: Local house in Mida Creek, Watamu

1.2.3 Housing conditions

In Kenya, the housing situation presents a significant challenge, as highlighted by Habitat for Humanity (n.d.). With an annual demand for housing estimated at 250,000 units and a supply of only 50,000 units from the government, the country faces a staggering deficit of 2 million units, constituting an 80% shortfall. This scarcity shows the issue of housing affordability, with many individuals unable to purchase or construct their own homes with quality products, according to interviews with Kenyan locals. Notably, only 2% of formally constructed houses are aimed at accommodating lower-income families. Consequently, a substantial portion of Kenya's urban population, approximately 6.4 million people, resides in informal settlements, exposing them to heightened health risks such as malaria, respiratory infections, and parasitic jigger infestation.

Responsibility for housing delivery primarily falls upon county governments, which often grapple with inadequate resources (Habitat for Humanity, n.d.). The importance of housing in enhancing the well-being of individuals and communities is underscored by McLeod (2018) and Nzau (2018). Adequate housing not only fulfills a basic physiological need for shelter but also fosters family cohesion, promotes health, ensures security for individuals and their belongings, and contributes to overall prosperity.

However, despite its significance, the focus of both public and private housing developers in Kenya has been on catering to the middle- and high-income groups, neglecting the affordable housing needs of the lower-income and poor segments of society (Kieti et al., 2020).

Housing material

In Watamu, there are three types of housing: temporary homes made from wood and mud, semi-permanent homes that mix mud walls with some cemented walls and coral stone, and permanent houses constructed entirely from coral stone, often cemented and plastered for added durability. Most houses fall into the temporary or semi-permanent categories. Roofs are typically either traditional thatched Makuti or iron sheets for wealthier families.

Residents usually build their own homes, resulting in structures lacking proper foundations and stability. Mud houses are popular for their affordability and minimal material requirements. However, upgrading to a sturdy permanent home can be costly, especially with the increasing prices of cement and coral stone in the local market, as found while interviewing construction workers in Watamu.

Housing market

When entering the housing market in Kenya, it's crucial to recognize the cultural nuances, as highlighted by Noppen van A. (2012). Different segments of the population, particularly low-income individuals, may have distinct aspirations regarding homeownership compared to those in other contexts. Understanding these cultural nuances can unveil new challenges or opportunities that were not present in previous experiences.

Moreover, it's essential to understand that housing encompasses more than just physical structures; it's also about community infrastructure. A holistic approach to housing development should not only focus on houses but also essential community amenities such as schools, clinics, places of worship, and recreational spaces. Most importantly, fostering a sense of ownership among residents is imperative. Developers must consider both the physical and social aspects of community building to ensure the sustainability of the project and prevent it from transforming into a slum or an abandoned settlement.

During the research period in Watamu, it was observed that community engagement regarding housing holds significant importance for residents. While their houses primarily serve as shelters or protection from the elements, the surrounding environment and activities outside the home are often deemed more significant. This external space is where residents spend the majority of their time and derive value from their housing situation.

Challenges

The housing state in Kenya faces various challenges and opportunities, as stated in the previous paragraphs. One significant aspect is the transformation that homeownership brings, offering not only financial security but also improved health and dignity (Noppen van A., 2012).

However, Kenya has been slow in adopting alternative building technologies, primarily favoring traditional materials like stone or wood (Noppen van A., 2012). Despite efforts to introduce alternative materials into the market, there remains a lack of confidence among consumers. To overcome this challenge, developers must ensure that homes built with alternative technologies closely resemble traditional structures, providing a familiar look and feel to prospective buyers.

Nevertheless, there is potential for utilizing alternative technologies to reduce housing costs and enhance sustainability, aligning with the principles of the circular economy (Built Environment and the Circular Economy, n.d.). Embracing circular economy principles, like remanufacturing plastic waste, in the construction sector can yield improved returns on investment for investors and clients, while also contributing to carbon emissions reduction targets.

In summary, addressing housing challenges in Kenya requires not only addressing affordability and health concerns but also embracing innovative approaches that align with cultural values.

1.3 Introducing the Project

From the understanding of the context, four problem areas were found that this research project focuses on. This section introduces the four areas, which are further explained and addressed throughout the report.

1.3.1 Problem statements

Plastic waste pollution

The overall problem that is addressed is the plastic pollution problem in Watamu, which especially harms the local economy in Watamu. Plastic waste poses a significant environmental threat in Africa, particularly in aquatic ecosystems, as highlighted by Akindele and Alimba (2021). Especially in these coastal areas, the plastic harms not only the marine animals but also reduces tourism and the aesthetics of the coastal line (Chakraborty et al., 2022). Kenya, despite its relatively low waste per capita, faces significant challenges in waste management, with a staggering 92% of waste being mismanaged (Griffin & Karasik, n.d.). This means that waste often does not end up in landfills, or other designated sites, and ends up in the environment. The lack of proper waste collection services in rural areas and the inefficiencies in urban waste management systems contribute to this issue, allowing plastic waste to accumulate in the environment. Most of these materials end up as waste after their initial use, with a large proportion finding their way into the environment or illegal dumpsites. The limited recycling infrastructure further exacerbates the problem, with only a small percentage, around 10 percent, of plastic waste being recycled (Oguge, 2019).

Collaboration between government agencies, private sector entities, and international organizations like the United Nations Environment Programme (UNEP) has led to the establishment of plastic waste management programs at both national and county levels (UNEP, n.d.).

Kenya's proactive stance in combating plastic pollution includes landmark policies such as the ban on single-use plastic bags and restrictions on plastic items in protected areas. While the policy has shown positive results, challenges remain, such as premature disposal of reusable bags, which influences the climate and waste impacts (Griffin & Karasik, n.d.).

Towards a CE

EcoWorld is struggling make the transition from mere recycling towards circular design methods. Currently, they collect and sort plastic waste from beaches and streets, which they shred to sell to recycling companies. The problem there is that they are dependent on these recycling companies and that plastics made of PP (and PET) pile up due to their low market value. Two years ago, the company began prototyping a plastic brick, and they are eager to develop their current product portfolio. The problem is that they lack the knowledge and resources on which direction to take and what resources they need to grow their business. This problem derives from the underlying barriers in technology, policy and public participation (Ahmed, 2022). The most prominent is the technological barrier, where there is a lack of skills with these new emerging technologies. Next to that, there is a lack of funding and policy from the government. Their ambition is to become a circular plastic waste company and move from recycling towards upcycling. This understanding of upcycling centers on creating products from plastic waste that offer enhanced social benefits to end-users while managing the entire lifecycle of these products, which will be explained further in section 3.1.1.

The potential of upcycling for businesses in Africa is increasing with the developing understanding of the topic, which will be discussed in chapter 3. This report will dive deeper into the potential of this strategy and the possibilities for EcoWorld. A framework is developed to visualize the current gap towards circular design at EcoWorld and an improved way of circular design is proposed for the company to move away from mere recycling. Here it is found that integration of the end-user is an important step to successfully transition towards circular design methods.

Perception of CE

To research the integration of the end-user, the perception and attitude towards the circular economy needs to be addressed. As stated before, there is a growing willingness to address the plastic pollution in Kenya and the understanding of the problem is growing, but utilizing this material is not yet done properly. At the moment, there is still an existing knowledge gap that prevents the adoption of this new emerging material. By understanding the local attitude and involving them in the process of creating with this material, the awareness and attitude of the end-users can change (Muyiwa Oyinlola et al., 2018). This is achieved through interviews, observational studies, and co-creation sessions during a 4-week field research to Watamu. The local community is actively involved in the design process and together the potential of upcycled products is researched and their perception of this material is discussed. The end-users play a key role in the development of the concept directions discussed in this research.

Housing in Kenya

Another problem for end user is the inadequate living condition, which EcoWorld wants to improve with better structural housing. Housing in Watamu is very diverse. Many locals live in poverty and live off of the tourism industry. In Watamu there are three types of houses in general; mud and wood houses, coral stone houses, and brick and/or concrete houses. This is also ordered from low to high income in the local community. Unfortunately, the lower income houses are most common in Watamu and lead to bad sheltering and low health conditions. This problem is critical as adequate housing is one of human's basic needs. As local Kenyans mention in interviews, the problem is not with the availability of the houses, but it is just not affordable for most of the local people. It was found that next to the poor structure of the houses (see figure 9), the hygiene of the houses was also poor to maintain for the homeowners. With a lack of storage possibilities, and a lot of dirt everywhere due to the mud walls and floors.



Figure 9: Holes in walls of a house in Watamu

1.4 The Stakeholders

From the context and problem statements, two main stakeholders were found that this research focuses on; EcoWorld and the local end users. To gain a comprehensive understanding of these stakeholders, interviews and observations were conducted, primarily in Watamu, during a four-week field visit.

This project is done in collaboration with EcoWorld, a small non-profit organization in Watamu, Kenya. EcoWorld is currently collecting waste, recycling it, and selling it to bigger recycling companies, but they want to expand their business. EcoWorld's main mission is to keep plastic waste out of the waste stream, by creating dynamic value chains, seeing women and youth as the main drivers for this economy. This project researches the possibilities for EcoWorld to grow its business by looking at the local housing market, taking a bottom-up approach to understand the end-user's perspective. This end-user is also explored in this section to get a comprehensive overview of their values and needs with this project.

1.4.1 Stakeholder mapping

To create a full overview of the different stakeholders, a stakeholder map was made. The visual on the side illustrates the various stakeholders involved in this research, highlighting their involvement in the project, their relationships, and the benefits they gain from this research (see figure 10). This overview will be revisited at the end of the research to assess whether the needs of all stakeholders have been met and how they can be further integrated into the project. This chapter focuses on the first two stakeholders depicted in the visual due to their high level of involvement.

As shown, there are several different stakeholders, each with unique needs from this research. Therefore, it is important to consider these diverse stakeholders during the design phase. Their needs and requirements must be understood to identify the best possible solutions.



Figure 10: Stakeholder Map

LOCAL HOME-OWNERS

A developed household to raise a family in a safe and secure environment. With a house to contribute to the local community and be able to follow your cultural traditions.

The end-user is of course the consumer of the products developed by EcoWorld. In this research they are also crucial in the development of the design proposal. They know best what they want and are there to help with understanding the market and the future developments within EcoWorld.

The end-user will be able to have access to affordable products that they helped develop themselves, which will help develop desirability. The products will also help with cleaning up the living environment of the end-user and bring socio-economic benefits as well with job opportunities for example.

EMPLOYEES AT ECOWORLD

Creating new products with the collected plastics from EcoWorld. Developing new products with the technologies given, to recycle plastic waste and give it a second life.

The manufacturers at Ecoworld specialize in the current manufacturing technologies at EcoWorld and know the limitations and possibilities with the current products. They are responsible for the quality and innovations of the products built at EcoWorld.

This research will bring the opportunity for manufacturers to learn new manufacturing technologies with collected plastics and will broaden their product portfolio to create more job opportunities and a diverse workforce.

BEACH CLEANERS

Collecting waste from beaches and from streets to clean up the local environment. Sorting and cleaning the plastic waste once collected to distribute further down the supply chain.

This stakeholder has less relation to the project but they do help with the cleaning and gathering the right materials to produce the right material. Especially in the cleaning and sorting, their expertise is valuable in this project.

This research output will not create immediate benefit for this stakeholder, but it will also create more job opportunities and create more understanding about their value within the supply chain.

LOCAL CONSTRUCTION WORKERS

Building safe and secure housing that are durable. Which are cost-efficient for the company but also the end-users.

The construction workers are the ones handling the products made by EcoWorld to build new houses with their construction material. They give insights into their expertise towards the construction and help develop the design proposal towards a realistic goal.

The products will create new materials that are more affordable for the construction of houses while also keeping their expertise in mind.

1.4.2 EcoWorld

Around 2010, plastic pollution emerged as a significant concern in Watamu, drawing attention from the tourism sector, environmental organizations, and local government. The Watamu Marine Association initially served as a liaison among these stakeholders. Out of WMA, EcoWorld as a non-profit organization emerged to address the plastic pollution issue with a practical approach, focusing on beach cleanups. Their efforts extended to creating employment opportunities for women and youth, because of the big inequality, while simultaneously igniting the local economy and preserving the environment. Over time, EcoWorld expanded its operations, incorporating machinery for plastic handling and recycling.

“EcoWorld’s overarching goal is to extend the lifespan of plastic waste by integrating it into dynamic circular value chains, thereby minimizing its presence in waste streams. We aim to simplify participation for the local community and envision women and youth as primary agents driving the circular economy along the coast.” Steve Trott, 2024.

However, EcoWorld faces several challenges. Foremost is the effect of a false market created by larger companies from Nairobi, which receive subsidies from big Western corporations. These companies buy plastic waste from local collectors for a higher price than EcoWorld can afford. Resulting in a drop of plastic waste collected at EcoWorld. Meanwhile, the local collectors get used to this high market value of plastic waste, which will drop when the market goes back to normal. This false market now negatively influences the collection of plastic waste at EcoWorld, and in the future will create a disrupted market with unequal pricing for the local collectors. Additionally, limited resources hinder their expansion beyond recycling into the creation of dynamic plastic waste value chains to support local enterprises.

Employees at EcoWorld

Collectors

EcoWorld depends on informal waste pickers to gather and sort waste materials for recycling. These waste pickers rely on their practical experience to help establish closed loops for materials, turning waste into valuable resources (Gutberlet et al., 2020). By working in the field, they become more aware of the risks associated with unregulated dumping, including health hazards.

Because of their firsthand knowledge, waste pickers can effectively educate others about the importance of separating waste at its source and identifying recyclable materials. This makes them valuable partners for social enterprises aiming to promote a shift towards a circular economy, especially in economically disadvantaged areas (Cau, 2022). This attitude can potentially be very interesting for EcoWorld to benefit from these experiences to narrow the distance between the end user and the plastic waste.

Workers on site

At EcoWorld, formal employees manage the handling of collected waste upon its arrival at the facility. The plastic waste undergoes a specific process outlined in the waste stream, shown on the next page (figure 11). These employees are local Kenyan people who express concern about plastic pollution in their country and are driven to contribute to addressing this issue. They recognize the economic potential of plastic in Kenya, which inspires them to advocate for its proper management and utilization. Educating themselves, their families, and neighbors about the possibilities with plastic is a priority. Looking ahead, they are eager to acquire knowledge in manufacturing techniques to transform waste into valuable products, thereby fostering economic opportunities for local businesses, despite the current knowledge gap in this area.

Current Waste stream

In figure 11, EcoWorld's current waste stream is shown. All the data was found by interviewing and observing the employees of EcoWorld. The company gathers waste from three main sources. At the facility, they begin sorting and shredding the incoming materials. A significant portion is sold to larger recycling companies, while a smaller fraction is utilized for producing items such as keychains through injection molding. Beach cleaners and local communities are compensated approximately 10 ksh (7 eurocents) per kilogram of plastic waste, while hotels pay around 5000 ksh (36 euros) monthly for EcoWorld's waste collection services. On average, employees earn approximately 15,000 ksh per month (110 euros per month). Packaged and shredded plastics are sold to recycling companies, with HDPE fetching the highest price at around 50 ksh per kg (36 eurocents). Revenue from selling recycled plastic constitutes the largest portion of EcoWorld's income, accounting for roughly 40 percent of the company's overall revenue, while the shop contributes around 15 percent. Additionally, the company organizes tours for tourists and schools in Kilifi County, which serves as an emerging revenue stream.

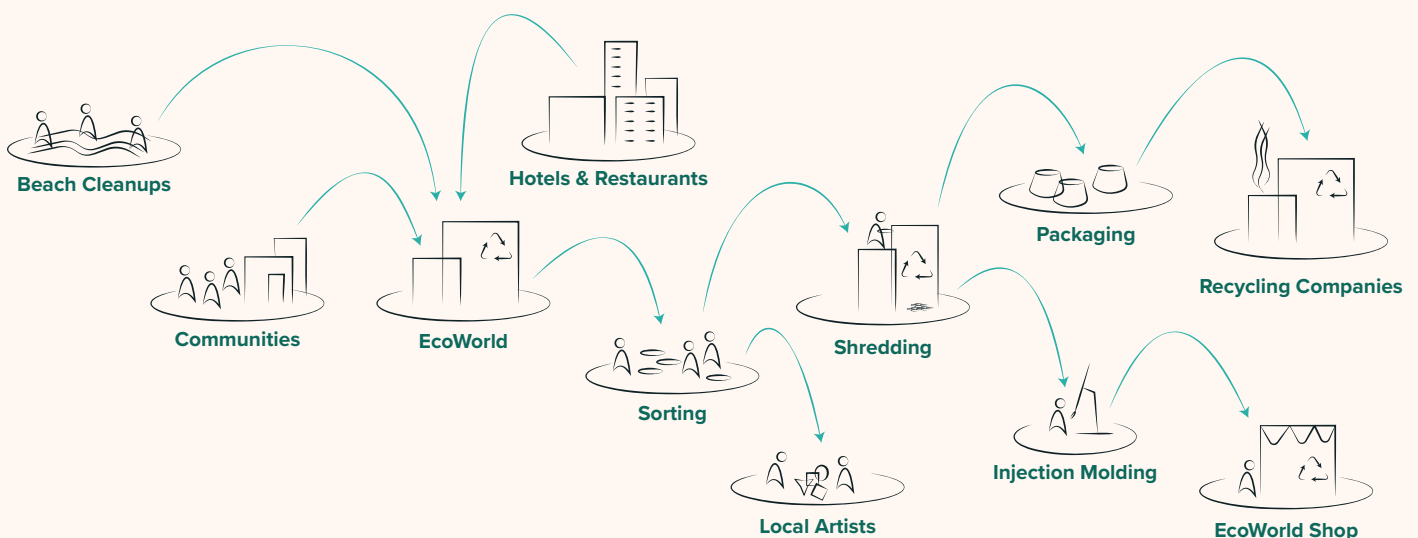


Figure 11: Current waste stream

Envisioned Waste stream

Each stakeholder in the waste stream benefits from collaborating with EcoWorld. Beach cleaners and community members, especially youth and women, gain access to new job opportunities for picking up waste, and fostering a new economy. Furthermore, hotels and restaurants can dispose of their waste sustainably, aligning with their sustainability objectives. EcoWorld also generates employment opportunities for locals, enabling them to enhance their knowledge of plastic recycling and develop skills at EcoWorld. The envisioned waste stream, see figure 12, incorporates end-users and proposes a method to slow down the waste loop.

By implementing new technologies beyond injection moulding at EcoWorld, employees can enhance their skills beyond current levels, offering new ways to create value for end-users. This expansion allows the company to cater to the diverse needs of end-users. These new products can be retailed at the EcoWorld shop or preferably distributed to small local enterprises, thereby fostering growth and job creation for local entrepreneurs. Involving end-users stimulates the closure of the loop and adds value along the chain at each stage. Consequently, waste ends up at EcoWorld because of the involvement of end-users with EcoWorld.

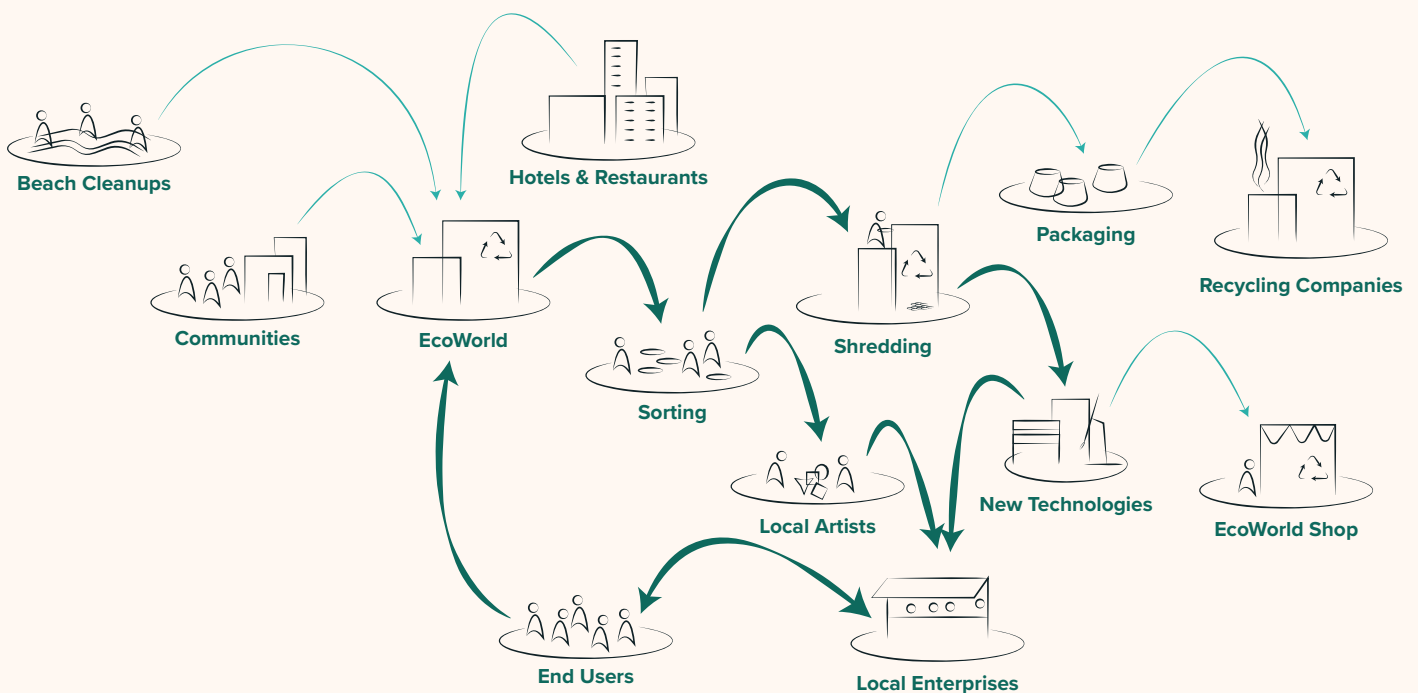


Figure 12: Envisioned waste stream

1.4.3 People of Watamu

Local End User

Another primary stakeholder in this research is the local population of Watamu, the end users of the products produced at EcoWorld. Understanding the end users and their context is crucial for this research in terms of integration and acceptance of the designed products. To achieve this, a persona was created to provide an overview of the end users, including their concerns, beliefs, and values. The focus of this research is on the low- to middle income households in Watamu. The average income of this target group is around 6000 ksh per month, which is around 45 euros a month. Key takeaways from the interviews and observations, conducted to understand the users, include their practical and hands-on mindset, their growing awareness of plastic waste, and their poor living conditions.

The people of Watamu are relationship-oriented, valuing family and community above all else. This cultural trait underscores the importance they place on having a good living situation where they can invite the community into their homes. Additionally, they are culturally rich and traditional in their ways of living, showing reluctance to change their lifestyles significantly. This cultural context is essential when considering the needs and values of the two different stakeholders involved in this research. Both perspectives must be integrated to guide the development of effective solution directions. These insights are shown through a persona in figure 13.

Construction workers

The construction of houses in Watamu is primarily done by homeowners themselves, who initially construct temporary mud houses before eventually building permanent structures when enough money is saved. Interviews were conducted with local construction workers to explore the existing construction process and their attitude to new materials. It was observed that many houses in the area are in poor condition, significantly impacting the living conditions of the lower-income community. Construction workers are actively seeking alternative materials due to the rising costs of coral stones. While they express openness to new materials, they remain cautious about market readiness. Some workers have experience with plastic materials and exhibit enthusiasm about their potential, citing numerous advantages over traditional coral blocks. The advantages are the weight, the low cost, and the applicability for example. However, they anticipate a gradual introduction of such materials into the local market due to perceived market readiness concerns.

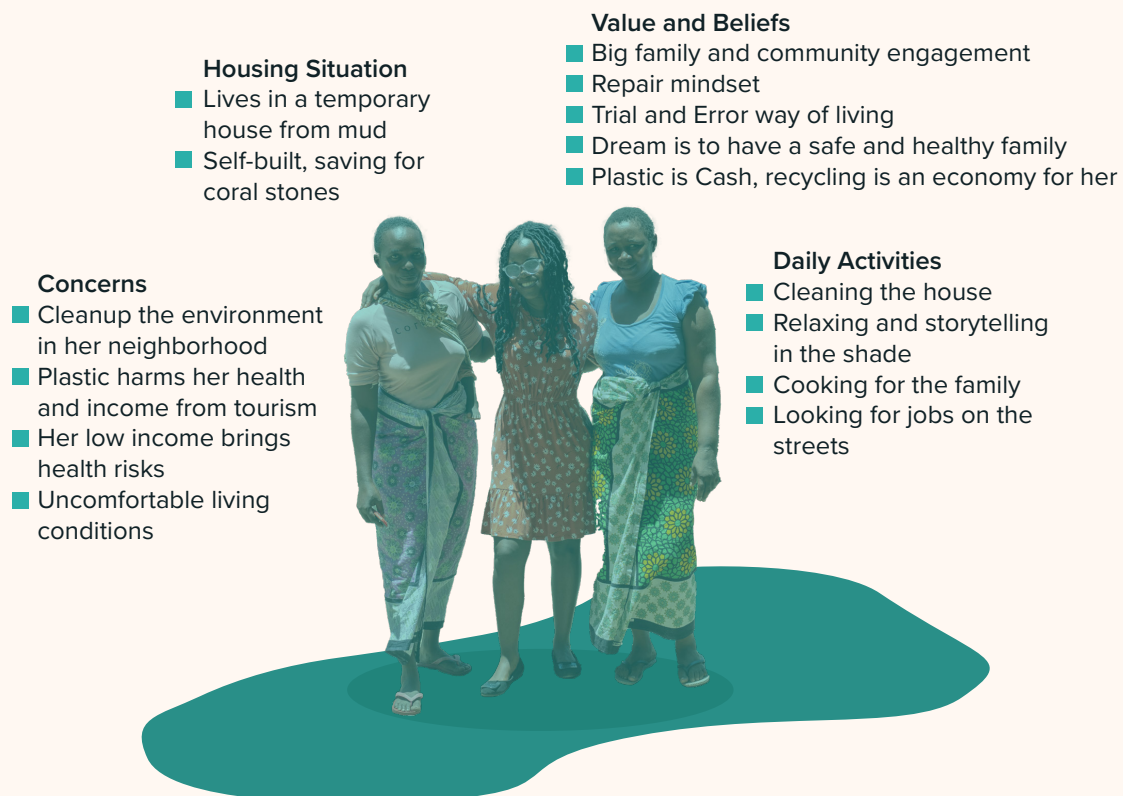


Figure 13: Persona

1.5 The Research Aim

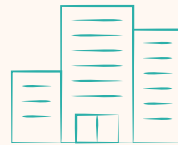
This section funnels down towards the main purpose of this research. Addressing plastic pollution, how to help EcoWorld shift towards circular design, and how to integrate end users to create products that; fit in the market, and improve the current living conditions. These problem areas are defined in three main challenges that are addressed with this research.

1.5.1 Purpose of this research project

This project aims to expand EcoWorld's product portfolio with meaningful design of housing utility products made from upcycled collected plastic waste for local Kenyan people to address the problems stated before. This will help the company build a more diverse portfolio with ideas designed with and for the local end users. These concepts can be used as stepping stones for the company to develop its expertise and understand the local market. This research will help them set out the next step to growing their business by building new partnerships and understanding new (local) technologies. These concepts will focus on improving the current living conditions of the end users and making their living conditions more safe.

Scope

The project will target low and middle-income households in Watamu, Kenya. EcoWorld aims to avoid direct competition with local commercial construction industries but intends to enter the consumer market by offering utility items for households. Their goal is to stimulate small enterprises to utilize EcoWorld products. Therefore, the project will concentrate on utility items related to housing, excluding structural components, using locally collected plastic waste, and incorporating circular strategies beyond mere recycling to create value for the community. The products need to be designed in a way that they can be produced locally, by the local employees at EcoWorld.



Company Challenge: Transforming Recycling into Upcycling

How might we design products that help EcoWorld to shift from traditional recycling practices to innovative upcycling methods, thereby maximizing the potential of waste materials?



End User Challenge: Addressing Inadequate Housing, and Closing the Knowledge Gap

How can we create solutions that simultaneously improve the inadequate housing conditions, and enhance public awareness about the impact of plastic on the environment and health?



Waste Management Challenge: Mitigating Aquatic Pollution for Sustainable Tourism

In what ways can we implement effective waste management strategies, particularly focusing on aquatic environments, to preserve marine ecosystems and enhance the sustainability of tourism industries?

1.6 Key Takeaways and Design Requirements

Key takeaways from context overview:

- 1.1 Watamu suffers from one of the highest poverty rates in the country with a big inequality in pay.
- 1.2 Watamu has a harsh climate with high heaths and Monsoon seasons.
- 1.3 PP (and PET) pile up at EcoWorld, while they have no purpose for them.
- 1.4 Big recycling companies from Nairobi create a false market for plastic waste collection.
- 1.5 In the construction industry it is not as easy to implement alternative materials.
- 1.6 The local community has a practical mindset, where they see plastic as cash and a valuable material for use.

Key takeaways from the End-user analysis:

- 1.7 Local Kenyan people have a practical and hand-on mentality and like to build and repair themselves.
- 1.8 Community and family is most important for them.
- 1.9 Their culture and ways are aspects of their living conditions that are hard to change, they like to stick to what they know and have.
- 1.10 Advantages of using plastic in construction are seen, but not yet accepted at this point.

Key takeaways on the housing status:

- 1.11 Adequate housing is one of the basic needs of a human, and in Kenya, this need is not met for most of the population.
- 1.12 It is not about the availability of housing but it is more about the affordability for the locals because the focus is now more on the high-income households.
- 1.13 A comprehensive understanding of the cultural context and the diverse nature of housing is essential for successful and sustainable housing projects in Kenya.
- 1.14 Integrate cultural values when developing products in the Kenyan context.
- 1.15 Integrate the cultural aspect of houses in the design. Align the design with cultural values.

Key takeaways from EcoWorld analysis:

- 1.16 A big part of EcoWorld's mission is to see women and youth as the drivers for the emerging plastic recycling economy.
- 1.17 The employees have a growing understanding of the negative effects of plastic.
- 1.18 The employees are open to innovation and technology at EcoWorld.
- 1.19 At the company there is a gap in knowledge on how to close the waste cycle.

Design requirements

- Involve local women and youth in the design process, and create job opportunities for them.
- The design should be produced locally and made with local resources.
- The design should create more awareness about the mission of EcoWorld among the end-users.
- The design should create more financial value for EcoWorld than the current products.
- The design should use PP and PET waste material as source material.
- The design should be able to survive the harsh climate conditions.
- Focus on creating job opportunities for local women and youth to decrease inequality.
- Make the products more affordable than the current products in the market.
- Involve the community in the design and development of the products.

1.7 Conclusion

Watamu faces significant challenges, including high poverty rates, income inequality, and a harsh climate with extreme heat and monsoon seasons. EcoWorld is accumulating large quantities of PP and PET without a clear purpose for them, while large recycling companies from Nairobi are disrupting the plastic waste market.

Adequate housing remains a critical need for much of the Kenyan population, with affordability being a major issue as current housing solutions primarily focus on high-income households. Successful and sustainable housing projects in Kenya require a deep understanding of cultural values and the diverse nature of local housing needs. Integrating these cultural values into product development is essential.

The local community in Watamu is characterized by a practical and hands-on mentality, with a strong emphasis on building and repairing items themselves. Family and community are of high importance, and there is a deep attachment to cultural traditions, making changes to their way of life challenging. Although there is growing recognition of the benefits of using plastic in construction, widespread acceptance has not yet been achieved. However, the local community's practical mindset sees plastic as a valuable resource. This perspective presents an opportunity to explore innovative uses of recycled plastic in addressing housing affordability and sustainability.

EcoWorld aims to position women and youth as key drivers of the emerging plastic recycling economy. Employees at EcoWorld are increasingly aware of the negative effects of plastic and are open to embracing innovation and technology. However, a significant knowledge gap exists regarding how to effectively close the waste cycle, both at EcoWorld and amongst the local community.



Figure 14: Scenic photo of the visit to a local village

02

Design Approach

This chapter outlines the design process employed in this research project. The first section provides an overview of the approach, establishing a structured framework for the process. Following this, the specific design activities undertaken in each chapter are explained. A deeper exploration of two primary research methods, field research and co-creation, follows, highlighting their purpose and benefits for this project. At the end the key takeaways and design requirements are clustered.



Figure 15: Photo of a creative session

Chapter Overview

- 2.1 Design Process
- 2.2 Design Activities
- 2.3 Field Research
- 2.4 Co-Creation
 - 2.4.1 Generative Approach
 - 2.4.2 Why this method?
 - 2.4.3 Preparations of the sessions
 - 2.4.4 During the sessions
- 2.5 Key Takeaways and Design Requirements

2.1 Design Process

This research utilizes a generative and iterative design approach, leveraging design methods and principles to address various problems. This problem-solving strategy uncovers actionable opportunities and fosters creative solutions while also considering implementation. A bottom-up approach is primarily employed, actively including end-users in the creative design process. This method enhances satisfaction and acceptance of the designed products, integrating local values and culture.

To structure the design process, an extended version of the Double Diamond Approach is used. The visual on the side, based on the Design Council's (2005) model, illustrates the dynamic process of converging and diverging (figure 16). Various design techniques are used to enrich this process.

The first section of the visual represents the research phase, focusing on identifying and defining the problem, including a field trip to Kenya. During this phase, design sprints were conducted to actively apply the bottom-up approach and introduce various design activities. The next phase is the design phase, where the generated ideas are developed into a final concept, with consideration for local context implementation. The extended Double Diamond Approach visualizes the comprehensive range of design activities used throughout this research.

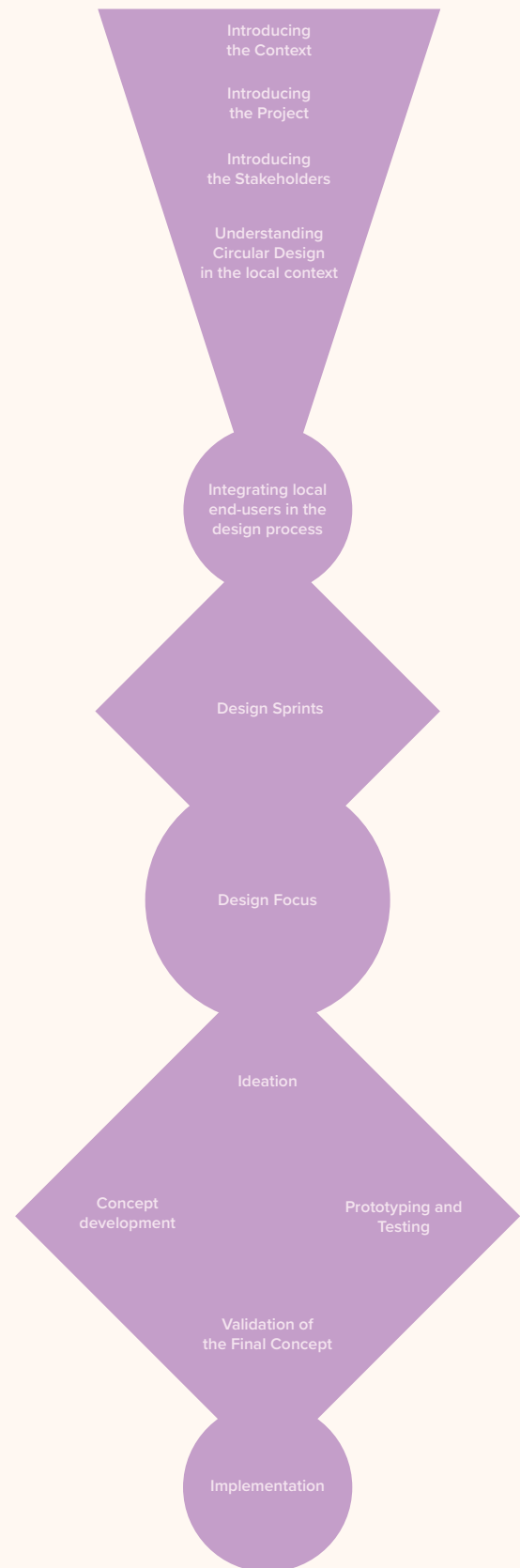


Figure 16: Extended Double Diamond approach

2.2 Design Activities

This section addresses the various design activities and research activities that were used in each chapter.

Understand the context

- Desk research to gather insights into the living environment of Watamu.
- Observations at 7 different houses to see the possibilities in housing.
- Interviews with 20 local community members to understand their perspective on living in Watamu, and get a better understanding about the culture.

Understanding the stakeholders

- Interviews with 20 local community members about their living conditions.
- Interviews with 10 employees from EcoWorld about the company.
- Interviews with the management of EcoWorld about the company.
- Observations at EcoWorld to see the current facilities.
- Observations at 7 different houses to see their current housing conditions.
- Desk research to understand the different relations between the different stakeholders.

Understanding Circular design in Watamu

- 2 expert interviews to get a deeper insight into circular design.
- Desk Research to define a circular design approach and how to integrate that in developing countries.
- Desk Research to see possibilities to create a business with this design approach.

Integrating the different stakeholders in the design process

- Interviews with 20 local community members to understand their perspective on the problem stated.
- Interviews with the management of EcoWorld to understand their struggles and their vision.
- Interviews with 10 employees of EcoWorld to understand their struggles and ambitions.
- Observations at EcoWorld to see growth potential and define problem areas.
- 3 Co-creation sessions with 4 local community members each session, to get a better understanding of the end user's perspective and integrate them into the design process.
- Prototyping to test feasibility of new innovative designs in the local context.
- Clustering and decision making together with the stakeholders to come to a unified decision.
- Developing 4 design sprints to create a clear process during the field trip to communicate the plan to the different stakeholders.
- Desk research to deepen the context of the research based on the insights gathered up to this point.

Design Focus

- Validation with the management of EcoWorld to choose a direction that fits with the companies vision.
- Validation with 7 local households to choose a direction that fits in their local culture, tailored to their needs.

From ideas to concept

- Ideation session to integrate the design focus towards a set of final idea directions.
- Rapid lo-fi prototyping to test small ideas and mechanisms.
- Inspiration from fellow design students, experts and field research to gather inspiration and see what works in the field.
- Creating 3 concepts to choose from based on the design focus.
- Choosing methods based on the requirements to go towards one final concept direction
- Validate the 3 concept directions with 11 end-users to choose towards a final concept.

Final concept

- Creating a final concept based on all the requirements to further detail the concept.
- Make sure that the concept fits in relation to all the involved stakeholders.
- Prototyping to test and showcase the shape and joining mechanisms.

Validation

- Interviews with 10 EcoWorld employees to make sure that the concept is viable and feasible in the local context.
- Interviews with 10 End-users to test the desirability, and if it solves the problems stated before.
- Testing the prototype with the end-user to gather feedback on iteration possibilities.
- Iteration on the concept to enhance its usability and production to finalize the project.
- Showcase the impact that the concept can make in regards to the problems stated before.

Transition model

- Crafting a transition model to grow as a business towards their envisioned mission.

2.3 Field Research

A field research was conducted to gather data within the cultural context. Over the course of four weeks, four design sprints were carried out to implement all the different design methods. Observations and interviews were conducted to gain a deep understanding of the context. This section discusses the relevance of design sprints for this report through media and literature reviews, as well as the preparation for these sprints. It also highlights the importance of traveling abroad to collect data in the local context.

Design sprints are utilized to accelerate the project and encourage the designer and team to make swift decisions throughout the process. This method enables rapid progression through the design process and facilitates the exploration of various research topics. Employing this approach aids in swiftly understanding and validating concepts, ensuring comprehensive research within the project's time constraints (Knapp, 2016). The design sprint approach was chosen because it allowed for a structured approach to achieve the deliverables that were set in preparation for the field research. These deliverables were established by the design team to provide a clear end goal for the field research. Because of the different stakeholders and the continuous iterative process, the deliverables made the use of the design sprint method ideal. The design sprint helped structure the research and enabled quick decision-making week by week. This organized approach ensured that all research questions were addressed and that the planning stayed on track toward achieving the desired outcomes. The preparation of the design sprints can be found in Appendix B.

Engaging directly with involved stakeholders was imperative for this research, especially when designing within a different culture. Immersing oneself in the local context helped adjust and iterate the process and set up various design activities. Being in Watamu allowed for observation and interviewing of local communities, aiding in the exploration of possibilities and assessing the feasibility and viability of the designs.

Additionally, it provided a learning opportunity for EcoWorld employees, who actively participated and learned about setting up various design activities. Field research was crucial for applying the bottom-up approach used in this project. Establishing face-to-face interactions with local communities and building relationships ensured valuable and thorough insights.

In preparation for the field trip, co-creation sessions were planned as the main design activities, and other activities were scheduled to enrich the data and refine the sessions. More information about creative sessions and the importance for this research is explained in the next section. Prior to the field research, extensive communication with the company addressed goals, expectations, and logistics, ensuring both parties understood the purpose and objectives of the field research (the goals are shown in appendix B). Communication with local communities was also initiated before the field trip to inform them about the research and invite them for interviews. The plan was developed iteratively, with each week's results implemented the following week, leading to deeper and more meaningful learnings. Chapter 4 details these learnings and explains the different design activities in greater depth.

2.4 Co-Creation

Co-creation is a design method used during the field research in Watamu. This section delves into the method in depth through media and literature studies. Additionally, it outlines the preparation for co-creation sessions, detailing how the research was translated into actionable sessions for data collection. This section will examine the relevance of co-creation for this report and discuss how to effectively prepare for and conduct co-creation in a different cultural context. Finally, key takeaways are summarized, concluding with an overall conclusion.

2.4.1 Generative approach

Co-creation, as defined by Mota (TU Delft, n.d.), is a collaborative approach that involves understanding the everyday processes of life and actively engaging users in the design and decision-making processes. By incorporating the perspectives and contributions of users, co-creation builds trust, fosters community ownership, and creates solutions that are more meaningful and sustainable over time. Mota emphasizes that co-designed spaces become integral parts of users' lives, evolving alongside their needs and aspirations.

This approach stands in contrast to the more traditional "top-down" development methods, where decisions are made without consulting local inhabitants. As Smits (TU Delft, n.d.) explains, this one-sided approach often results in projects being implemented without considering the unique needs and capacities of the community. Consequently, when projects are handed over to local communities, they may lack the resources or expertise needed to maintain and operate facilities effectively. Co-creation seeks to address this issue by involving communities from the outset, ensuring that solutions are tailored to their specific context and empowering them to take ownership of the outcomes.

2.4.2 Why this method?

The bottom-up approach of co-creation is recommended for several reasons. According to Ind and Coates (2013), meaning is not solely determined by creators or organizations but emerges from interactions among stakeholders. This highlights the significance of involving various parties in the creation process to ensure that solutions resonate and remain relevant. Additionally, Galvagno and Dalli (2014) propose that incorporating customer experiences can significantly enhance innovation and customer satisfaction. This alignment of products and services with customer expectations is seen as crucial for fostering long-term engagement and loyalty.

"A deep understanding of the local psyche is not just a 'good to have' but a 'must have'" (Chavan & Prabhu, 2010).

Schneider (2005) further emphasizes the shift towards co-creating value with customers rather than viewing value creation as solely the responsibility of firms. By actively involving end-users in the value-creation process, firms can better understand their needs and preferences, leading to improved satisfaction and potentially gaining strategic advantages. Moreover, Schreier, Fuchs, and Dahl (2012) found that products designed with user input tend to lead to increased purchase intentions and willingness to pay. This underscores the value of user-driven innovation in enhancing consumer perceptions and loyalty.

Beyond commercial implications, co-creation is seen as particularly impactful in the realm of social value creation. According to Sanders and Simons (2009), social value co-creation requires direct engagement, visualization of collective assets, and the right mindset to succeed. This approach emphasizes the importance of real-time interaction and empathy for those affected by change, highlighting co-creation's potential to drive meaningful social transformation. As discussed in the previous section, it is important to have this engagement to transform the perception of circular economy strategies. By involving the communities in the design process awareness and understanding will be created, to ensure this meaningful social transformation around circular behavior.

Within this research, the generative side of co-creation is used. To look further than the Say (interviews) and Do (observation) studies and emphasize the Make techniques. This technique generates more opportunities for exploring experiences at a deeper level and reading between the lines of your end-user's input. With the co-creation sessions, it is key to find the right balance between these Do, Say, and Make techniques. The next part of this section will explain how these generative techniques are combined in this research to create sessions fit for this study (Sanders, 2020).

In summary, co-creation is advocated for its ability to foster innovation, enhance customer satisfaction, and drive social impact by involving various stakeholders in the creation process, thus ensuring that solutions are not only effective but also resonate deeply with the intended audience.

2.4.3 Preparation of the sessions

In preparation for the co-creation sessions in Watamu, a deep dive into cultural sensitivity was done to prepare for conducting research in a different cultural context. The activities during the sessions and the time management was piloted together with fellow designers before travelling to Watamu. The detailed preparations of the sessions are shown in appendix B. The actual process and takeaways derived from the sessions and the research trip to Watamu can be found in chapter 4.

During co-creation sessions, the designer takes on the role of facilitator, maintaining a neutral stance to foster trust and encourage collaboration. Additionally, having a cultural translator present is essential for navigating cultural differences effectively. While actively involved in session preparation and duration, the translator ensures cultural appropriateness without oversimplifying (Eriksen, 2019). Pilot sessions with the translator helped refine the design activities and ensure cultural relevance.

Culture sensitivity

Cultural sensitivity is a key factor in the design process, highlighting the need to incorporate various cultural aspects (Dhadphale, 2017). These aspects often include diverse values found in different cultures, which can sometimes be challenging to understand, as discussed by Visser et al.. Co-creation sessions provide an excellent opportunity to gain insights into these cultural nuances.

Developing cultural sensitivity involves considering different cultural dimensions, as outlined by Erin Meyer in “The Culture Map” (Meyer, 2015). In the context of research conducted in Kenya, this means taking into account factors like communication, leadership, trust, decision-making, and scheduling. In the graph on the side (figure 17), the Netherlands and Kenya are compared on different cultural dimensions defined by Erin Meyer. Here you can see that there are big cultural differences between the two countries. It is imperative to understand these dimensions, to be able to facilitate sessions and do research in a different cultural context. This will result in valuable insights and culturally appropriate research methods. Especially in a setting where hierarchical leadership structures and relationship-based trust play significant roles. Observations during the research trip indicated that having men present during sessions could negatively affect outcomes, leading to the decision to include only female participants. Building on a relationship before the sessions was key, with participants already familiar with EcoWorld and the facilitator.

To further develop this existing relationship, a very simplistic storyline toolkit was built. With this toolkit, the participants could already get familiar with generative tools and the research topic. Flexibility is vital for facilitators throughout the project, allowing them to adapt to changing circumstances and recognize the subtle nuances in communication, which often go beyond superficial insights.

To prepare and perform the co-creation sessions in a different culture a methodology is used to set up co-creation sessions across cultures (Eriksen, 2019).

THE COUNTRY MAPPING TOOL

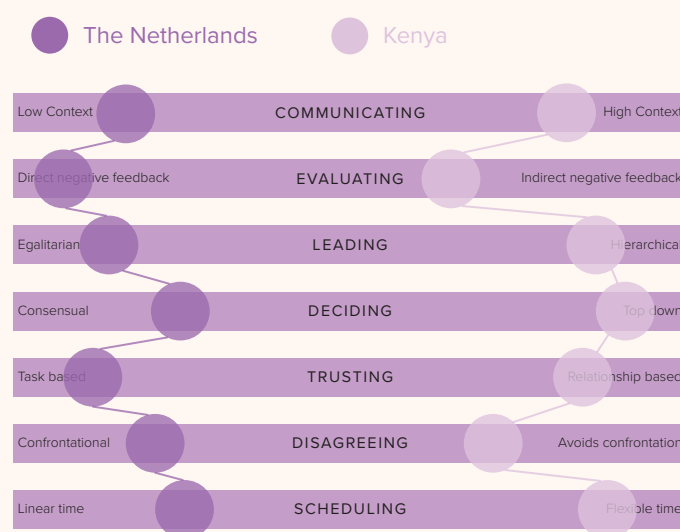


Figure 17: The Country Mapping tool between the Netherlands and Kenya (Meyer, 2015).

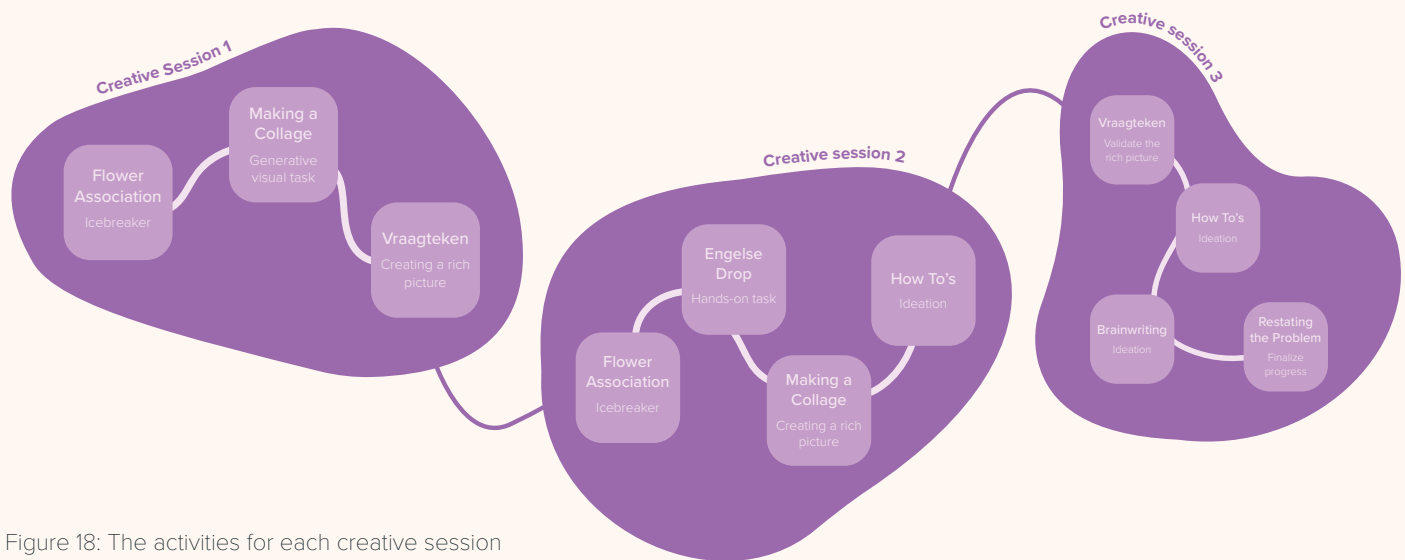


Figure 18: The activities for each creative session

2.4.4 During the sessions

At the beginning of each session, it's crucial to set clear expectations for the participants. They should understand that all contributions are valued, and they are encouraged to engage actively in the activities. Participants are seated in a circular arrangement, promoting interaction, with tools placed in the center for easy access. Timing is discussed to allow for breaks and address any questions or concerns about the session structure.

The sessions are designed to be generative, focusing on hands-on activities to delve deeper into the input. The session built-up is shown in figure 18. The activities were chosen from different books with various creative tasks, the books used are; Road Map for Creative Problem Solving Techniques (Heijne, 2019), 101 ideeën voor ideeën (Heijne, 2022), Delft Design Guide (van Boeijen, 2020). Next to these books, the Convivial Toolbox (Sander, 2020) and the ones mentioned before were used to build and prepare the sessions outside of the activities, focusing on planning and general tips and tricks on facilitating creative sessions.

The sessions are highly visual and interactive, fostering collaboration and creativity. The sessions are designed to build upon each other, with icebreakers to ease into the sessions. These activities have been culturally adapted with the assistance of a cultural translator to ensure relevance and inclusivity. The same was done for the interview questions that were used throughout the whole field research.

To maintain consistency and participant familiarity, some activities are repeated across sessions (see appendix B for the full outline of the activities).

The choice of the co-creation method stems from its potential to create social impact by involving end-users in the design process. This approach encourages acceptance and satisfaction with the final product, leading to more effective and enduring designs. Involving the community in both the design and validation phases ensures cultural appropriateness and enhances research impact. However, there are limitations to consider. Sessions are conducted in an unfamiliar cultural context with a different language. This may result in missed nuances or difficulties in explanation, despite the assistance of a cultural translator. Additionally, participants and the cultural translator are non-designers, potentially limiting creativity during activities.

Data collection involves the use of videos and photos for post-session analysis, supplemented by facilitator notes on conversational nuances. The visual activities will be used in result analysis, offering insights into contextual understanding and potential solution directions. Results are analyzed after each session, to improve the next session and to be able to converge more each session. This will lead to generative insights into the context, problem, and potential solutions.

2.5 Key Takeaways and Design Requirements

Key takeaways from co-creation

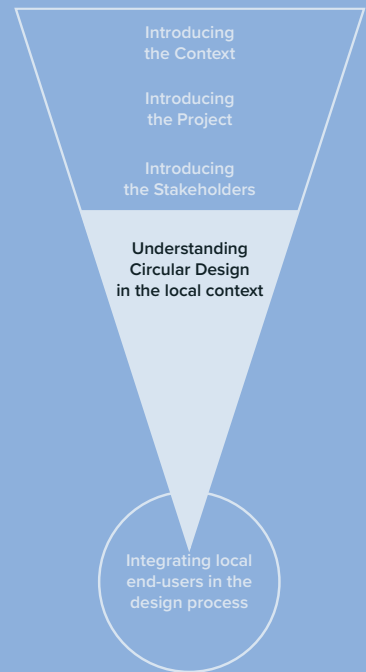
- 2.1 The co-creation method should be used to achieve a social value impact which leads to higher consumer satisfaction.
- 2.2 Co-creation sessions should be generative to understand a deeper level of experiences.
- 2.3 The cultural dimensions of the Kenyan culture need to be researched in preparation of the field research.
- 2.4 In preparation of, and during the sessions, a cultural translator is imperative to design culturally appropriate sessions and understand the nuances during the research activities.
- 2.5 The creative sessions should be designed for cultural appropriateness to achieve a greater acceptance and satisfaction amongst the end users.
- 2.6 Using the 'bottom-up approach' will help ensure that solutions are tailored to the specific context and empower to take ownership of the outcomes.
- 2.7 The design process should involve the end users to build effective and long lasting loyalty.

Design requirements

- Involve end-users in the design process to encourage satisfaction and long-lasting solutions
- Design should be made and understood by local workers for better implementation



Figure 19: Active involvement of the local communities



03

Understanding what circular design is in the local context

This chapter delves deeper into the research phase, focusing on understanding how a circular economy can be implemented in Kenya. Through media and literature studies, it provides a general understanding of circular design, particularly upcycling. Expert interviews offer insights into real-life applications and local African use cases. The chapter also outlines how this approach can be integrated into businesses through a framework supported by literature. Additionally, it discusses the role of end-users in adopting this approach through literature studies as well as interviews, setting the stage for the next phase of the report. The chapter concludes with a summary of key takeaways that will inform the following chapters.



Figure 20: Artwork made by collected plastic waste

Chapter Overview

3.1 Defining CE in the Local Context

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3.1 Defining CE in the Local Context

3.1.1 Our Definition

The term “upcycling” is gaining traction within upcoming industries, particularly among enterprises aiming for a circular economy. However, a universally accepted definition is not there, as interpretations vary among specialists. Broadly speaking, upcycling involves transforming items into higher-value products compared to their original state. Yet, the concept of “value” is multifaceted and subjective. This section aims to define EcoWorld’s interpretation of upcycling, informed by a review of literature, interviews with experts, and observations within EcoWorld. This understanding of upcycling centers on creating products from plastic waste that offer enhanced social benefits to end users while managing the entire lifecycle of these products. This differs from the term often referred to as downcycling because the initial value of the product along the whole product cycle is increased, as opposed to downcycling where the value along the product cycle is decreased and there is only a focus on prolonging the end of life (Helbig, 2022). Additionally, the adoption of upcycling practices contributes to the circular economy by reducing production costs through the utilization of secondary raw materials (Horvath et al., 2018). This chapter will explore upcycling from a literature point of view, examining its implications in diverse contexts such as Africa and housing, along with strategies for developing a business model around this concept and how to design with it.

3.1.2 Upcycling introduction

Upcycling has emerged as a significant strategy for enhancing sustainability in recent years. This method, as noted by Singh (2022), not only aids in conserving resources and minimizing waste by reusing spare parts instead of purchasing new ones but also generates economic value and encourages social interaction within communities. When interviewing companies specialized in the circular economy, like Better Future Factory, the advantages of upcycling plastic waste were emphasized. They also see upcycling as a process that creates more value out of the waste material along the whole production line, from extraction to end-of-life. With their projects, they also saw the advantages of including the community, and building upon those social interactions that come along with implementing this new production method.

This upcycling approach holds particular promise for developing economies like Kenya, where there is a growing emphasis on repair, refurbishment, and repurposing of materials to achieve sustainable development goals. However, to fully realize the potential of upcycling in fostering environmental management and economic growth, technological innovations, and supportive business solutions are essential. In this context, exploring the concept of upcycling offers an opportunity to promote sustainable development, and advance environmental conservation efforts both locally and globally.

3.2 How is CE implemented in the current context

3.2.1 Upcycling in Africa

Upcycling initiatives in Africa are gaining traction, aiming to foster community development, combat plastic pollution, and create value. These initiatives, as highlighted by GRID-Arendal (2021), embrace the cultural, demographic, and economic diversity of African nations, necessitating an Afrocentric approach to circularity and the term ‘upcycling’. The transition towards upcycling, while rooted in traditional practices, has gained momentum as a means to inclusively integrate women and youth into sustainable development efforts because of the new job opportunities that it brings. Especially the young generation is very open to new jobs emerging in this field.

One standout example is Upcycle Africa, an organization committed to promoting environmental consciousness by re-educating communities through upcycling (Jahic, 2022). By transforming useless products into functional items, Upcycle Africa demonstrates the feasibility of a greener industry and profitable entrepreneurship. Additionally, individuals across Africa are adopting upcycling practices in their daily lives, further emphasizing the accessibility and practicality of this approach (Polity.org.za, 2013). In figure 21, a collage is made with some examples of successful upcycling companies in Africa.

Storytelling here plays a pivotal role in driving the success of upcycling initiatives, as highlighted by Janssen & van Dobbenburgh (2019). By narrating the journey of organizations and individuals embracing upcycling, storytelling contributes to the creation of value systems and accelerates the transition to a circular economy.

However, these initiatives face challenges, including the lack of affordable resources, expensive marketing, and negative perceptions about upcycled goods (Singh et al., 2019). Overcoming these obstacles requires collaborative efforts from various stakeholders, including government bodies, businesses, consumers, and activists. Success factors include raising awareness, legislative changes to redefine waste, and improving the overall purchasing experience for consumers (Singh et al., 2019).

In conclusion, upcycling initiatives in Africa, showcase the potential to promote community development, combat plastic pollution, and create value while navigating challenges that come with transitioning towards circular economies.



Figure 21: Upcycling examples in Africa

3.3 The Business Potential of CE

3.3.1 The Value Hill method

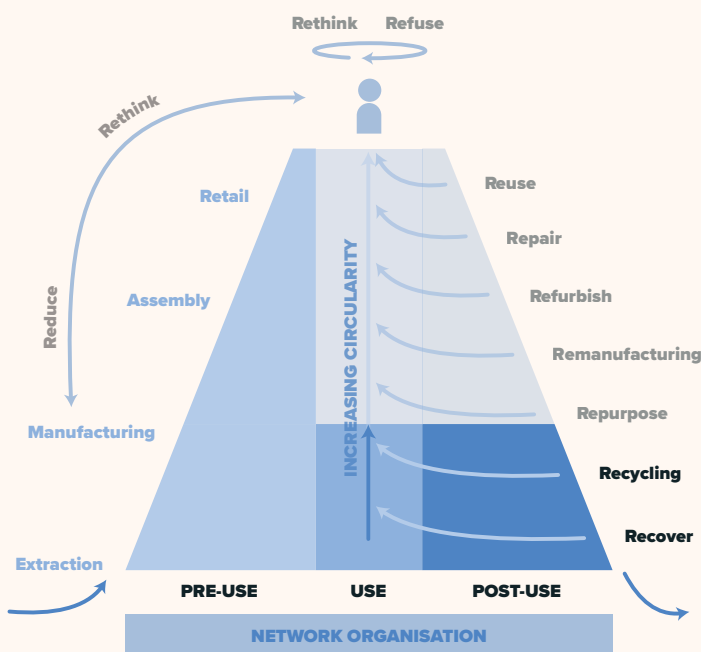
The Value Hill method, as described by Achterberg et al. (2016), is a strategic tool used by businesses to implement circular strategies effectively. It categorizes business activities into three distinct domains: uphill, top hill, and downhill, allowing companies to position themselves based on available resources. Uphill focuses on circular product design, while Top Hill emphasizes optimal product usage and Downhill centers on resource value recovery strategies. By understanding and strategically positioning across these domains, businesses can transition from a Linear Economy to a Circular Economy more effectively (Upadhayay & Alqassimi, 2020). This approach emphasizes the importance of managing resource flows, optimizing incentives, and supporting activities within a circular network, forming the basis for successful circular business models (Achterberg et al., 2016). In essence, the Value Hill method offers a structured approach for businesses to navigate and strategically adopt circular strategies within the circular economy framework.

EcoWorld on the Value Hill

In the visual below EcoWorld is put on the value hill to visualise their current approach to circular design (figure 22). This shows the potential for EcoWorld to move towards an improved circular design approach, creating more value with the material by focusing on the end-user and the end of life, by using other R-strategies than only recycling and recovering. This adds to the definition of upcycling that was stated at the beginning of this section. By moving up the pyramid with other R-strategies to create more value during and after use, the company moves away from mere recycling to an upcycling approach. Upcycling, as defined in this context, involves enhancing the social value of products crafted from plastic waste throughout their lifecycle by employing strategies beyond traditional recycling, aiming to maximize socio-economic benefits while managing the whole product life cycle.

ECOWORLD

POSITIONING ON THE VALUE HILL



Step 1: Position the current business model on the Value Hill.

Currently EcoWorld focuses on collecting and recycling of plastic waste in Watamu. They recycle by shredding plastic waste and bailing (mostly PET). In addition they offer small injection molded products as souvenirs in their shops.

Step 2: Position the value chain partners on the Value Hill.

EcoWorld works together with multiple government bodies and other companies that give them grants to stay alive. Next to that they have a very close relation with their employees from collectors to manufacturers, giving them job opportunities and good working conditions.

Step 3: Identify gaps and opportunities in the circular value network.

Currently the value of the plastic waste is very low, by shredding everything and selling this which indicates a lot of value loss after collecting it. In this value stream, EcoWorld is also not in contact with the direct end-user, which also is a lack of value that is lost in this value chain.

Step 4: Formulate the future circular business strategy.

EcoWorld's future mission is to create quality products from the collected waste, based on market needs. Next to that the company wants to grow from only recycling and look in ways of implementing upcycling methods. As a small company they are open to learn more about becoming a circular business and get more resources to grow the business.

Figure 22: EcoWorld on the Value Hill

3.4 How to Implement CE in the research context

With the understanding what upcycling means in our context and how a business model can be derived using the value hill method, this section will explore ways to implement it in the design process. This section explores the circular product life cycle and ways on introducing upcycling in housing and to the end users.

3.4.1 Circular Product Life Cycle

Literature studies reveal gaps in familiarizing the different circular economy terms and frameworks. In this research, we use an interpretation of the circular product life cycle, a framework established based on the model proposed by William McDonough and Michael Braungart (2022), with the integration of the different R-strategies introduced by Potting et al. (2007) (Sung, 2023) (see figure 23).

During the field research, each phase of the framework will be refined together with EcoWorld and the end users to fit to the local context. The most important aspects will be highlighted at each phase to ensure that future product designs fit the proposed framework and align with EcoWorld's vision. Including the user is imperative to optimize the product-in-use phase and ensure the end-of-life phase is properly managed. This framework will form the basis for the product designed in the next phase and serve as a reference for EcoWorld in future product developments.

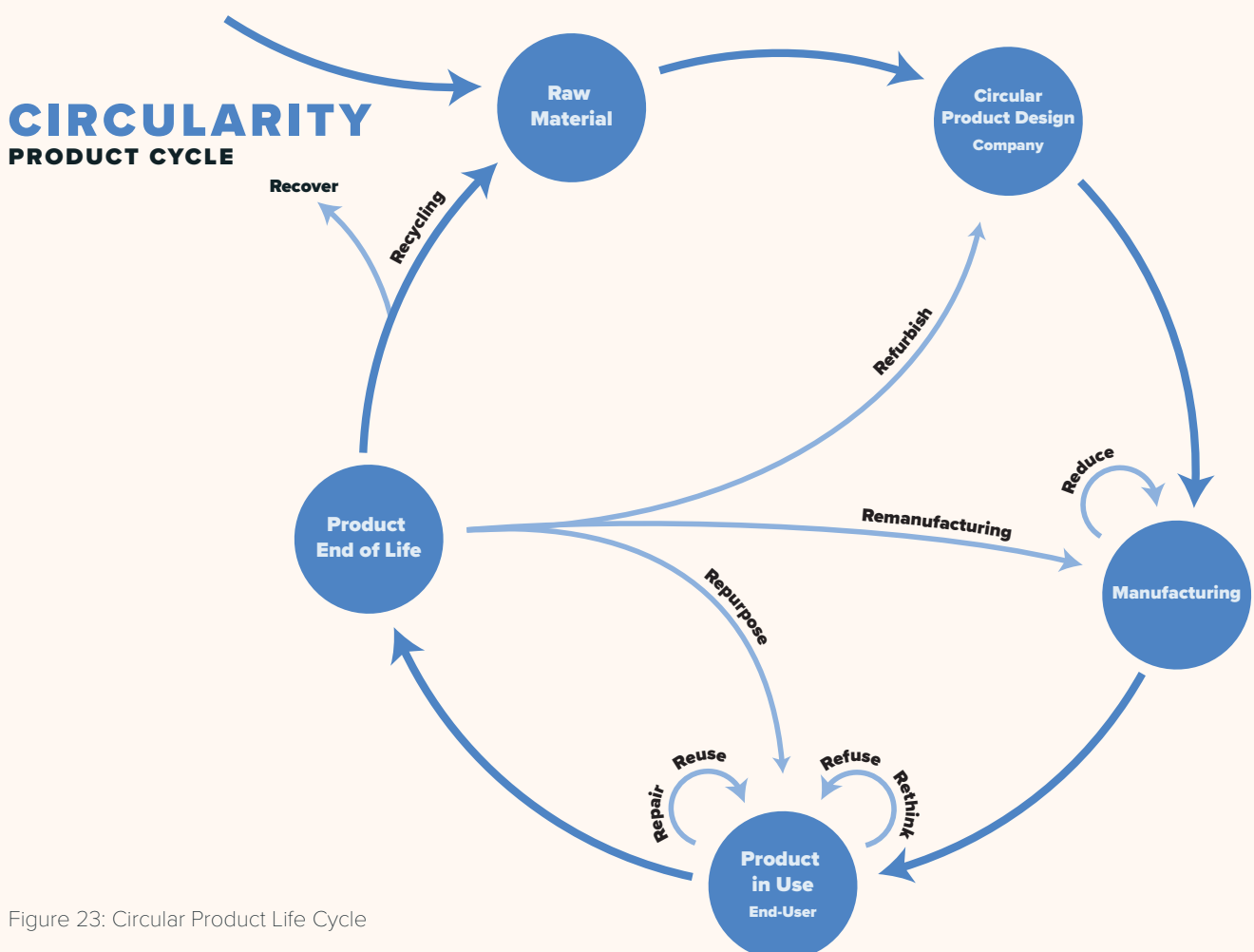


Figure 23: Circular Product Life Cycle

To fully realize a circular design approach, all stages of this model must be actively addressed by the design team, as well as the fit in the business their mission. EcoWorld already contributes to some phases of the cycle, performing a recycling approach with a mission to grow towards other R-strategies and closing the loop. Closing or slowing the resource loop avoids using new resources and energy, focusing on keeping products in use longer or only using materials that already exist (Bocken, 2015).

Thus, achieving a circular design approach involves slowing down the resource loops and ultimately closing them. Terms like futureproof, disassembly, maintenance, remake, and recycle are often mentioned in literature as opportunities in product design (Reslan, 2022). While closing the loop is the logical solution, it presents issues such as technical constraints, lack of user awareness, and end-of-life responsibility. Although closing the loop should be the ultimate vision, slowing down the resource loop and fostering new, efficient, and valuable products is an important first step (Mestre, 2017). Multiple design strategies support slowing the resource loop. Designing reliable and durable products, both emotionally and physically, can lead to long-lasting products. Focusing on maintenance, repair, and remanufacturing can extend product life, leading to a slower resource loop and eventually closing it (Bocken, 2015).

This report focuses on five phases in the product life cycle: Raw Material, Product Design, Manufacturing, Product in Use, and End of Life. These phases are chosen based on the proposed models and the representation by Reslan et al. (2022). Raw material selection plays a key role at the beginning of the cycle to ensure product functionality and quality (Reslan, 2022). The product design phase involves customer data as well as the integration of business facilities. In product design phase the foundation is made on how to address the following phases in the product life cycle (Kurilova-Palisaitiene, 2015).

Addressing the manufacturing phase helps reduce waste and resource scarcity, anticipating the product's end of life (Reslan, 2022). To ensure the circular product is adopted during the product-in-use stage, it is essential to produce a safe, efficient, and manageable product, ensuring it is used as intended and provides the right feedback on its state. The end-of-life stage is critical for slowing the loop from both the end user's and the company's perspectives. Focusing on correct collection, sorting, processing, and ensuring the product is easy to disassemble is vital. Effective end-of-life strategies are challenging, with infrastructure, behavior, and systemic issues. However, new technologies such as remanufacturing show promise in bringing products back to useful life effectively (Reslan, 2022; Kurilova-Palisaitiene, 2015).

3.4.2 Upcycling in housing

With this understanding of what upcycling is and how it can benefit both the users, the business and how to design with it, this report looks at the implementation possibilities in the scope of this project.

One notable example of upcycling in the housing context involves using sand-filled plastic waste bottles in building walls, offering cost-effective construction methods while mitigating overheating in tropical climates (Roberts et al., 2023). These bottle-composite walls contribute to reducing overheating and improving indoor comfort, highlighting the potential of upcycling in addressing construction challenges. This is an example of creating more social value and looking at the product life cycle as a whole, which makes it upcycling according to the definition stated earlier.

Understanding the nature of materials and their preservation is crucial in upcycling for housing (Ali et al., 2013). Designers play a pivotal role in utilizing waste materials effectively to ensure durable finishes that last over time. This approach not only appreciates existing resources but also raises awareness about environmental protection, fostering a sustainable balance between human needs and ecological preservation and taking regard for human health and material properties in different climate conditions.

Initiatives in sub-Saharan Africa, such as housing from plastics, demonstrate the social, environmental, and economic benefits of upcycling in housing (Quaye et al., 2022).

By reusing plastic waste and generating employment opportunities, these initiatives contribute to sustainable development while addressing housing challenges. Integrating circular economy principles through upcycling materials in construction offers significant environmental and economic advantages (Adefila et al., 2020). By reducing waste and construction costs, upcycling empowers communities to engage in sustainable practices and aligns with traditional values around sustainability and economic justice. Additionally, upcycled materials can be utilized for decorative purposes in buildings and interiors, adding visual appeal while promoting environmental friendliness (Gnatiuk et al., 2022). Through creative abstraction from the original function of materials, designers can create visually engaging spaces that reflect the origins of the materials used.

In conclusion, upcycling in construction and housing utility product design presents an opportunity to reduce waste, enhance sustainability, and create social value in the future. By interviewing locals in Kenya it became clear that at this point the trust in recycled plastic is not yet there for construction products. However, over time trust and knowledge will be built by implementing recycled products to create awareness. By embracing these innovative solutions and leveraging local resources, communities can start to build towards environmentally friendly and economically viable housing solutions. This last part will make housing more affordable for the local community in the future.

3.4.3 Integrating the user in the CE

As found in the literature, the end users should be integrated into the design process during this research project. In this chapter, the perception of the end user towards the circular economy is discussed to find opportunities and struggles for adaptation of this new emerging strategy.

Perceptions, as defined by Efron (1969) and extended by Boothe (2002), involve how individuals mentally engage with the world around them, shaping their personal experiences that are different for each person. In implementing sustainable development, a shift in values and behaviors across the value chain is crucial (Sharma et al., 2019; Giunipero et al., 2012). In East Africa, where institutional support for circular economy initiatives is just now coming up, community involvement emerges as critical (Cau & Ciambotti, 2022). Social enterprises, like EcoWorld, engage local communities in learning and decision-making, fostering awareness of circular economy principles (Oliveira et al., 2018). These community participations enhance the legitimacy of circular strategies and facilitate resource recycling (Holt & Littlewood, 2017). Social enterprises in areas like Nairobi emphasize the importance of community acceptance for their operations (Padilla-Rivera et al., 2020). In summary, perceptions influence engagement with sustainability, while community involvement is essential for fostering acceptance and legitimacy in low-income contexts.

3.4.4 Cultural Acceptance of CE

In African countries, cultural perceptions significantly influence the acceptance of sustainable housing solutions, including those involving recycled plastics (GRID-Arendal, 2021). The diverse cultural, demographic, and economic landscapes across the continent underscore the importance of developing localized approaches to circularity. Involving local communities in the design and construction process of sustainable housing fosters a sense of ownership and satisfaction, aligning with the United Nations' adequate housing program (Muyiwa Oyinlola et al., 2018; Abbakyari et al., 2023). However, cultural preferences for traditional building materials and aesthetics may pose challenges to the widespread adoption of innovative housing solutions utilizing recycled plastics. Concerns about the strength and durability of novel building materials highlight the need for community-driven solutions (Zami and Lee, 2009; Muyiwa Oyinlola et al., 2018). Engaging communities collaboratively and inclusively is essential to enhance the cultural acceptance of recycled plastics in housing, taking into account their values, needs, and preferences.

3.4.5 Current development in perception of CE

In African countries, there's a pressing need to integrate recycled plastics within local cultures to address plastic pollution (Oguge et al., 2021). Despite growing awareness, there's still a gap between knowledge and action, highlighting the necessity for targeted awareness campaigns (Oguge et al., 2021). The continent's youthful population shows a willingness to adopt new technologies, making it interesting for testing solutions for environmental problems like plastic pollution (Bilikiss Adebisi-Abiola et al., 2019). However, there's a lack of understanding regarding consumer perceptions and behaviors towards upcycled materials, including recycled plastics, in construction projects (Adefila et al., 2020). Research emphasizes the importance of considering socio-cultural requirements in housing construction and understanding consumers' decisions regarding circular economy practices (Adefila et al., 2020; Fátima Vidal-Ayuso et al., 2023).

Positive nudging of circular technologies, often referred to as the afterlife theory, emphasizes the importance of framing environmental messages positively (Winterich, 2019). Rather than focusing on negative consequences, this approach highlights the story of what happens to old products after they have been recycled. By emphasizing the possibilities and potential of recycling, individuals are inspired and become more aware of the benefits. The key to successful implementation lies in simplicity and timeliness, ensuring that messages are easy to understand and delivered at the right moment (Kamleitner, 2019).

Understanding consumer behavior is critical for circular economy implementation, as consumer acceptance and contribution to high-circularity products are essential (Shevchenko et al., 2023). Developing a product-centric framework for studying this behavior along the value chain can provide insights into attitudes toward products with the highest circular impact, enabling targeted efforts for systemic change toward circular consumption.

Transparency and extensive learning are vital for influencing consumer attitudes towards recycled plastic products (Oguge, 2019). Sharing experiences from users in the value chain can adjust behavior and contribute to the development of a new ecosystem. This ecosystem can create new revenue opportunities and inclusive jobs, addressing sustainable development goals like poverty reduction and gender equality.

In conclusion, integrating recycled plastic in African countries requires an understanding of consumer behavior, fostering transparency and learning, targeted awareness campaigns, and socio-cultural requirements to drive systemic change towards circular consumption and production.

3.5 Key Takeaways and Design Requirements

Key takeaways from Defining CE

- 3.1 With circular design in Africa there is potential for more community engagement because it is rooted in their culture.
- 3.2 Upcycling initiatives in Africa show the feasibility and accessibility of this emerging strategy.
- 3.3 By involving the end-user in the design process, the social interaction with the products is increased, which will lead to a better adaptation of this material over time.
- 3.4 By understanding the possibilities with a circular design, social value can be created for the local community, and it can also be more affordable.
- 3.5 There is a big gap in the value hill for EcoWorld to transition towards creating more business value by involving different R-strategies.
- 3.6 Creating the right look and feel with recycled plastic products, will help communities engage with plastic recycling and create awareness.
- 3.7 Essential for realizing a circular design approach by addressing all life cycle stages.
- 3.8 Slowing down the resource loop is an important first step to transition towards closing the loop.
- 3.9 Upcycling or circular design in this research is seen as transforming waste materials, particularly plastic, into higher-value products, thus conserving resources, minimizing waste, generating economic value, and fostering social interaction within communities, with a particular emphasis on inclusivity, community development, and environmental consciousness.
- 3.10 Focus on 5 phases in the circular product life cycle; Raw material, Product design, Manufacturing, Product in use, End of life.
- 3.11 User involvement is crucial for optimizing product use and ensuring proper end-of-life management.

Key takeaways from end user perception:

- 3.12 Involving the local community in the design process will create ownership, acceptance, and understanding of the topic.
- 3.13 Understanding the cultural context by building cultural sensitivity is imperative for success.
- 3.14 To understand the environmental impact of CE a framework should be made. This will help close existing the knowledge gap.
- 3.15 To increase adaptation the design can use positive nudging.

Design requirements

- The design should be made together with the local community
- The design should fit into the local context, including the local values and needs
- The design should help bridge the existing knowledge gap about recycled plastic products to create awareness about the possibilities.
- The waste loop should be closed by looking at the end of the life of the designed product.
- The product should be designed to be repaired easily, focusing on the product in use stage.
- Critical steps in the waste cycle should be improved.
- Involve the end-user in the design process to understand the product in use stage.
- The design should show that it is made of recycled plastic and make it fit in the local context

3.6 Conclusion

This report defines a way to shift from recycling to upcycling, signifying a move up the value chain towards other R-strategies. This approach suggests to transform plastic waste into higher-value products, by focusing on the product's use phase and generating social value. This chapter highlighted the significant potential of these strategies in developing countries in Africa, with multiple companies currently adopting this approach, demonstrating its feasibility and accessibility. This report visualized a circular product design approach with a framework that is further developed in the next phase of this research. This framework showed that during the design phase, the 5 different phases of the product life cycle should be addressed to achieve a circular design.

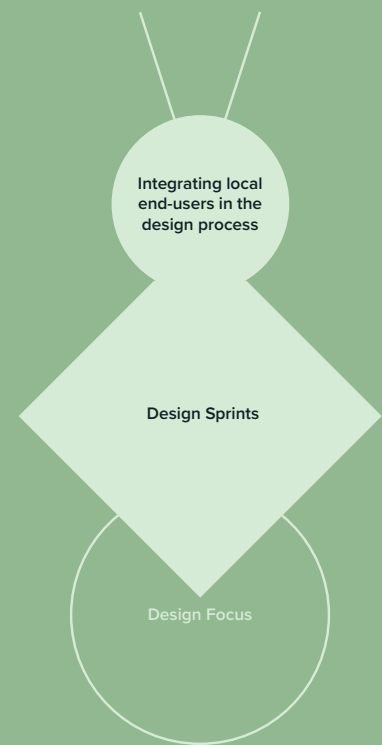
Kenya is recognized as a frontrunner in plastic waste management in Africa, and adopting this strategy holds great promise for the country. The design should create more social value and put emphasis on the product's use phase for better adaptation and acceptance of the material. Local end users should be integrated in the design process to foster ownership and to expand knowledge about the possibilities, thereby closing the existing knowledge gap in the recycling economy. Implementing this strategy in Kenya shows significant potential, supported by multiple examples and a growing understanding among local communities, which can be further developed with the right approach over time.



Figure 24: EcoWorld employees sorting plastic waste

04

Integrating the different stakeholders in the design process



Chapter Overview

- 4.1 Introduction
- 4.2 Design Sprint 1
- 4.3 Design Sprint 2
- 4.4 Design Sprint 3
- 4.5 Design Sprint 4
- 4.6 Deepening the research context
 - 4.6.1 Hygiene
 - 4.6.2 Items to Store
 - 4.6.3 Safety measures
- 4.7 Conclusion

4.1 Introduction

With a solid understanding of the circular economy and its integration into the local context, this report now examines how different stakeholders can be incorporated into the design process. It has become evident that both end users and the company are crucial for the successful implementation of circular design. This chapter explores methods for understanding and involving end users in the design process to collect data for the subsequent design steps. Four design sprints were conducted to gather this data, with the results and key takeaways presented in this chapter. In this chapter the key takeaways are presented after each Design Sprint, and summarized in the conclusion. Details on the preparation for these sprints can be found in appendix B.

The first sprint focuses on understanding the company's context and identifying opportunities within the organization. The desired outcome here is to establish a clear framework of their current eco-waste product cycle with design criteria and a well-defined problem statement. In the second week, the sprint shifts to examining the user context and addressing problem areas from their perspective. In addition to refining the framework from the previous week, this sprint aims to generate initial ideas collaboratively with the end users and create a holistic view of their living conditions.

Week three centers on validating the process and integrating stakeholders to collectively validate the chosen direction. The objective is to achieve a shared understanding of the project's direction, along with clear idea direction. Finally, in the last week, the sprint involved creating tangible prototypes based on the selected direction. Collaboratively with end users and the company, a prototype is developed to co-create and validate the design process.

Additionally, the last section delves deeper into specific aspects of the found design direction, enhancing the understanding of the local context. These aspects will be important in the later stages of concept development and serve as criteria to ensure the concept aligns with the local context and how the user interacts with the product.

The chapter concludes with a summary that wraps up the research phase and sets the stage for the design phase.

4.2 Design Sprint 1: Company Discovery

Design Sprint Approach:

This sprint focuses on delving into the company's structure, value streams, and challenges to gain a deeper understanding of its growth opportunities. The primary aim is to develop a framework highlighting both the current and desired future eco-waste product cycle, along with key criteria for product development focus.

Design Goal:

The goal is to explore the core values of the company and create a framework that effectively communicates opportunities for growth and innovation.

Methods Employed:

To achieve this goal, interviews and observations were conducted with the company's management and workers. Individual interviews with the management team provided insights into their perspectives, while discussions with employees handling plastic revealed valuable insights into the value stream and potential for implementing new technologies. Observations complemented these insights, helping to form a holistic picture to inform framework development.

Validation and Next Steps:

The developed frameworks underwent validation with the management team, allowing for iteration on criteria points and overall level of understanding. Ultimately, the finalized framework showcases both the current and future eco-waste cycle at EcoWorld, highlighting opportunity spaces and providing structure for newly developed products. This sets the stage for further exploration and development in subsequent sprints.

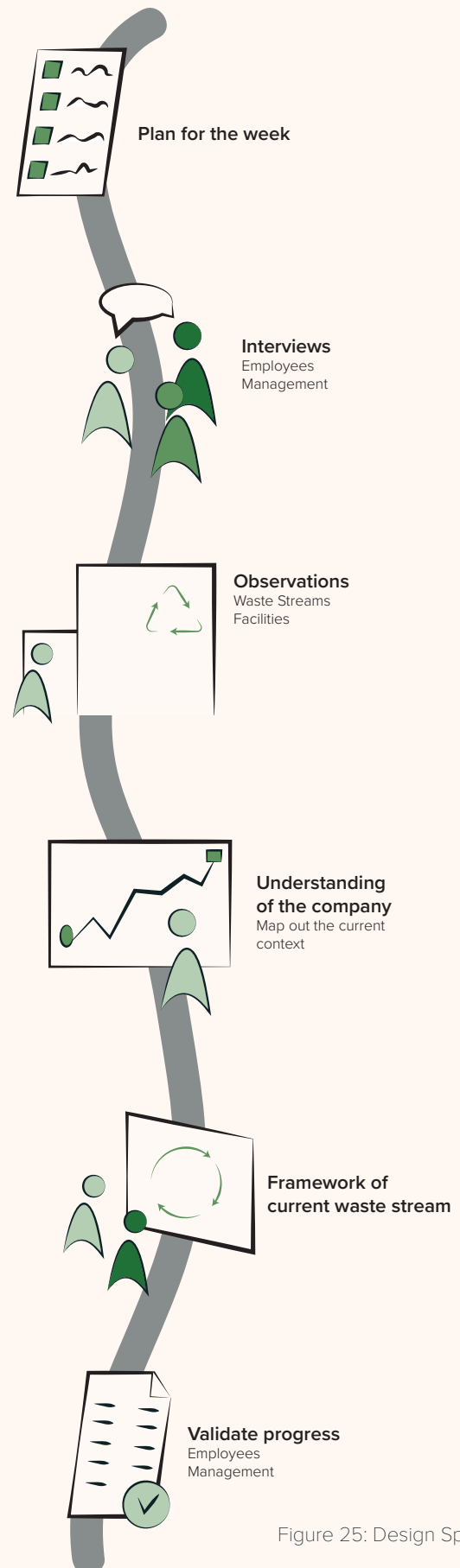


Figure 25: Design Sprint 1

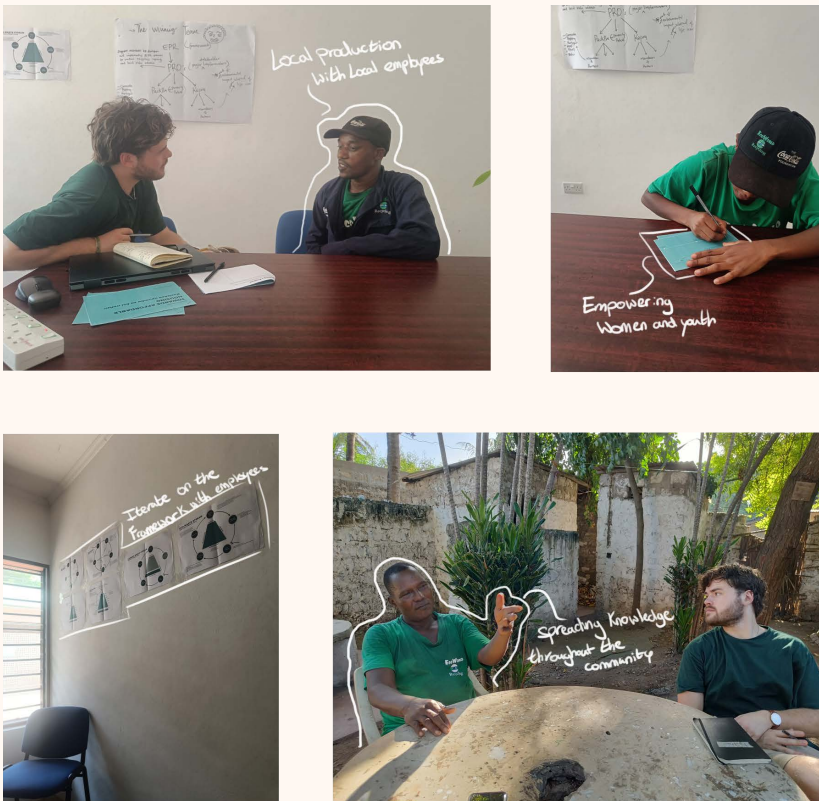


Figure 26: Interview insights with EcoWorld employees

This design sprint started with observations and interviews at EcoWorld alongside employees and management (see figure 26). The aim was to delve deeply into EcoWorld's values and mission, gaining insights into the current waste stream and potential to grow towards a more circular approach. From the interviews with EcoWorld's employees, it became clear that they were very invested in the organization's mission of environmental impact and the ignition of a new local economy for women and youth, all while raising awareness about plastic pollution. Employees even actively spread information within their communities, establishing a community education center to educate youth about the importance of plastic recycling. Interviews with EcoWorld's manufacturers revealed an openness to adopting new technologies and embracing the principles of a circular economy. Their willingness to engage in trial and error processes highlighted a readiness to explore new ways for product development and production.

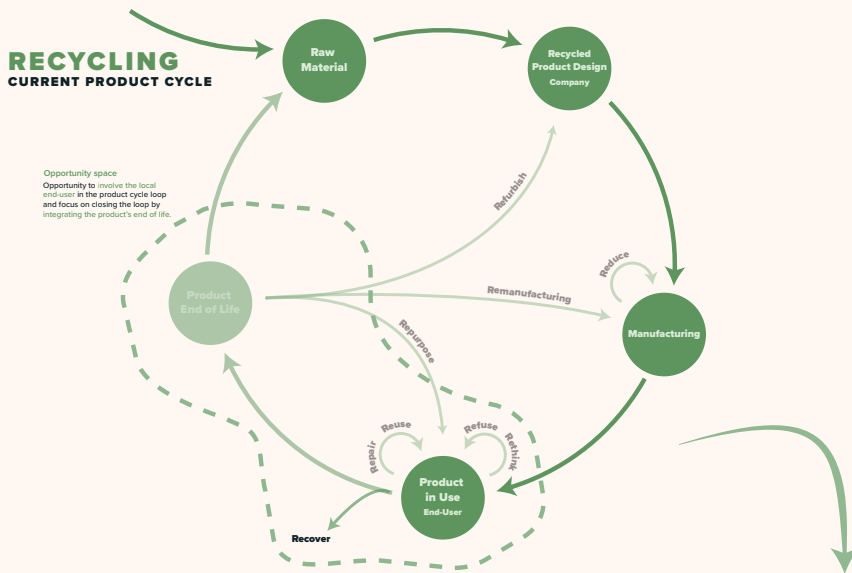


Figure 27: Current recycling flow with the potential gap highlighted

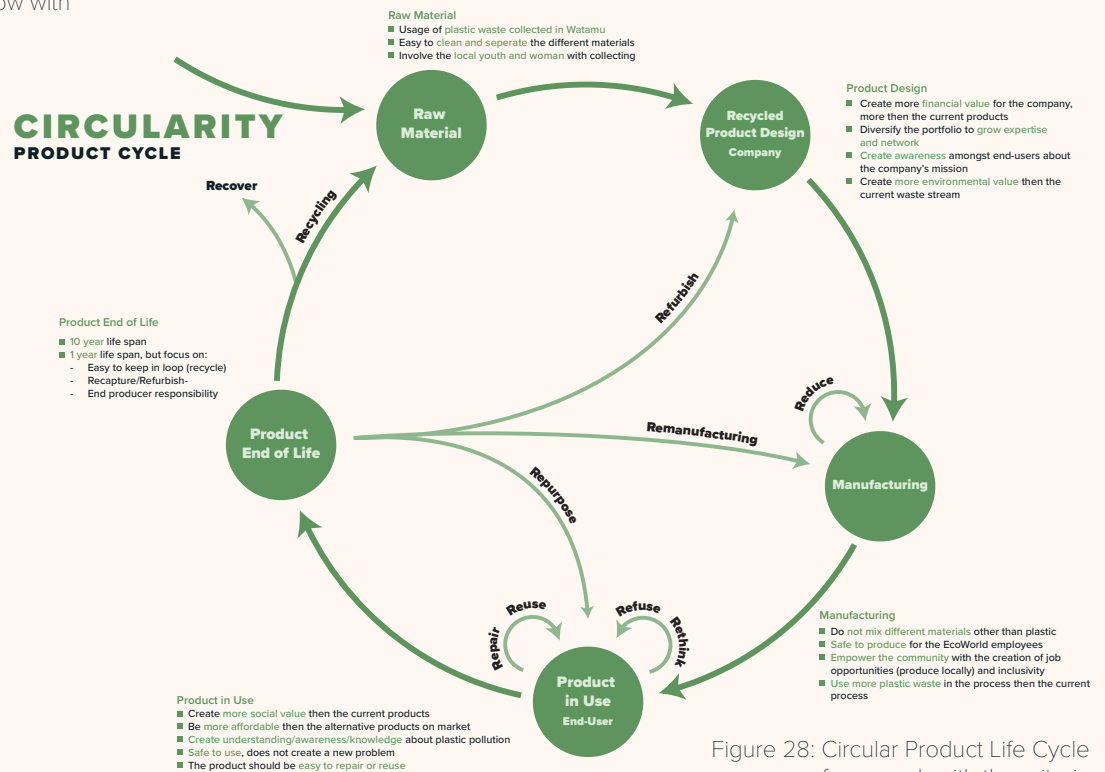


Figure 28: Circular Product Life Cycle framework with the criteria

Following the observations and interviews, the key takeaways were put into a framework to visualize the current waste stream and develop a desired product cycle that would slow down the loop. Adopting a product-centric approach we identified a critical opportunity within the product lifecycle (Shevchenko et al., 2023). The analysis revealed a gap in focus on the product's use and afterlife stages (see figure 27). EcoWorld now only has the keychain, which is not developed with the end user in mind. This gap presented an opportunity for research to enhance these stages while improving other aspects of the product lifecycle, facilitating a transition towards a circular economy at EcoWorld.

Together with EcoWorld, the criteria points were established at each stage of the product lifecycle, informed by key takeaways gathered during the initial week in Watamu, as well as the media and literature studies done in the previous phase. These criteria points, clustered around the product lifecycle, formed the basis for decision-making in the next design sprints. Ultimately, the goal is to identify concept directions that align with these criteria points, signifying a shift towards a circular design approach (see figure 28).

Key takeaways from Design Sprint 1:

- 4.1 Embrace opportunities at both user engagement and end-of-life stages.
- 4.2 Center on empowering the local community, focusing on women and youth.
- 4.3 Employees at EcoWorld show openness to adopting new technologies and exploring the principles of a circular economy.
- 4.4 Educating EcoWorld employees will spark community knowledge about handling plastic waste.



Figure 29: Employee drying the shredded plastic waste

4.3 Design Sprint 2: User Deep Dive

Design Sprint Approach:

This sprint aims to deepen our understanding of the problem context from the end user's perspective. Building on key takeaways gained from the previous sprint focused on the company, we recognize the important role of the end user in the waste cycle. This cycle immerses us in exploring the end user's needs and desires within this context.

Design Goal:

The goal is to explore the end user's context and comprehend their perspective within the research context.

Methods Employed:

Observations and interviews were used to gather insights on the context from 12 individual Kenyan locals. Initial interviews provided a superficial overview of the context, showing interesting problem directions. The observations within the community's homes offered firsthand experiences to delve deeper into these directions. The data gathered was used to enhance the two creative sessions involving four local Kenyan women in each session. These sessions aimed to explore identified problem directions at a deeper generative level. The first session focused on creating a rich picture of the context, while the second delved into understanding plastic materials and generating ideas based on insights collected.

Validation and Next Steps:

At the sprint's conclusion, various ideation directions were established. This exploration allowed for the discovery of different solution spaces. These directions were validated with the participants and collaboratively refined during the sessions. Additionally, validation was sought from the company, to conclude the direction for the next steps in the field research.

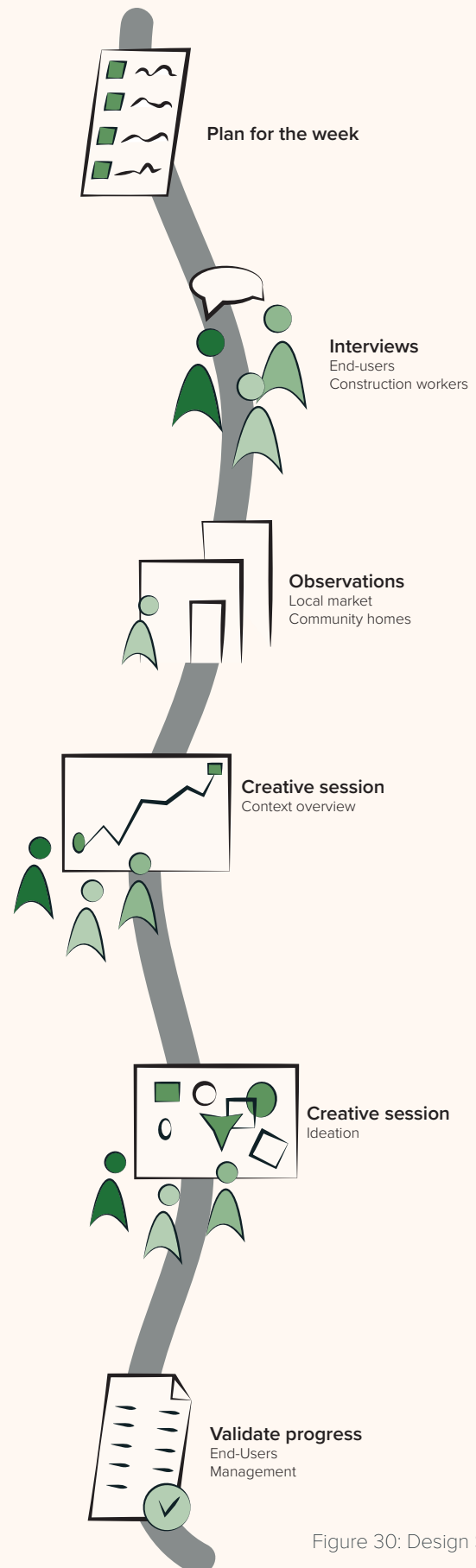


Figure 30: Design Sprint 2

At the beginning of this design sprint, interviews with 12 local Kenyan women were held to gain insights into the living conditions of the community in Watamu. Through these discussions, three primary problem areas emerged: Comfort in Shelter, Hygiene in the House, and Safety at Home based on the clusters seen in figure 31. The interviews revealed that residents spend much of their time outdoors due to the harsh weather conditions, but there is a lack of comfort in these shading places. Moreover, a strong emphasis on hygiene, driven by the status that a clean house brings in the community and regular hosting of guests, is hard to maintain due to housing structure and poor to no storage facilities. Safety concerns, coming from the poor structural integrity of mud houses and the threat of dangerous animals, further trouble the living conditions.

The other clusters highlight the attitude of the local communities towards plastic pollution and using plastic as material for products. It was found that they are very aware of the negative impact of plastic pollution to their environment. The other clusters show their practical and ‘fix-it’ mentality, focusing on durable products, which life they prolong by repairing them at the end of life. Next to that, they gave an overview of their living situation mentioning the harsh climate conditions, and the various products they have at home.

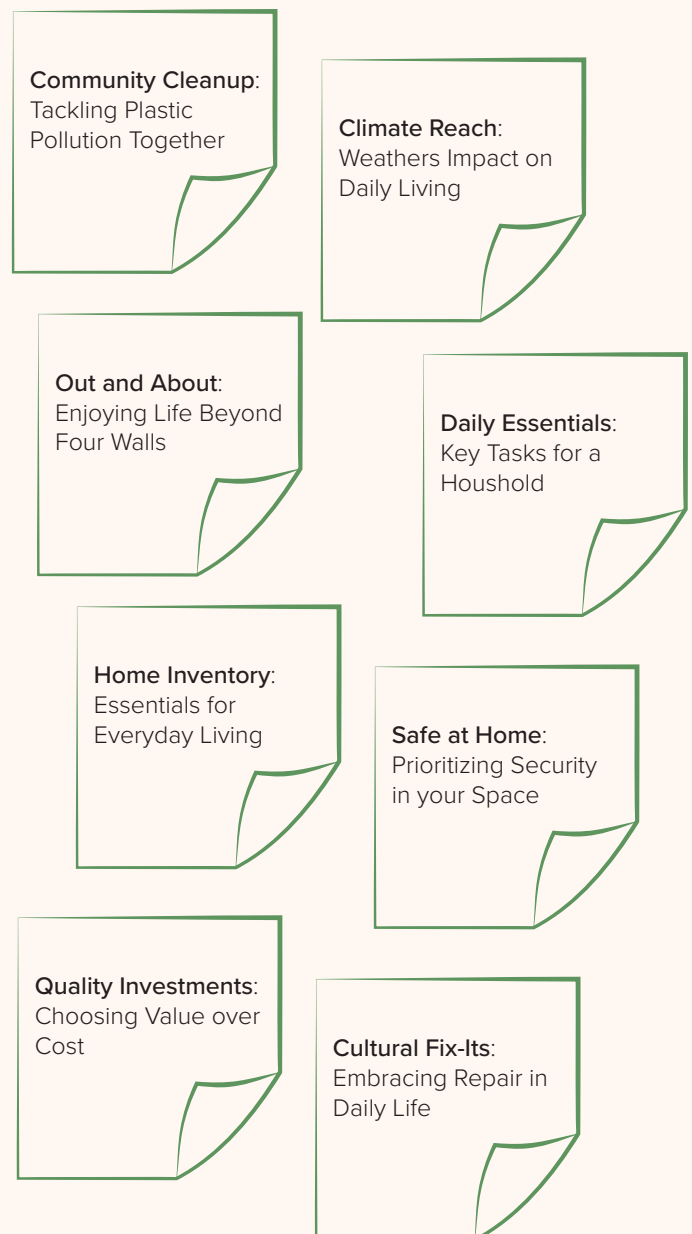


Figure 31: Clusters of the insights from end user interviews

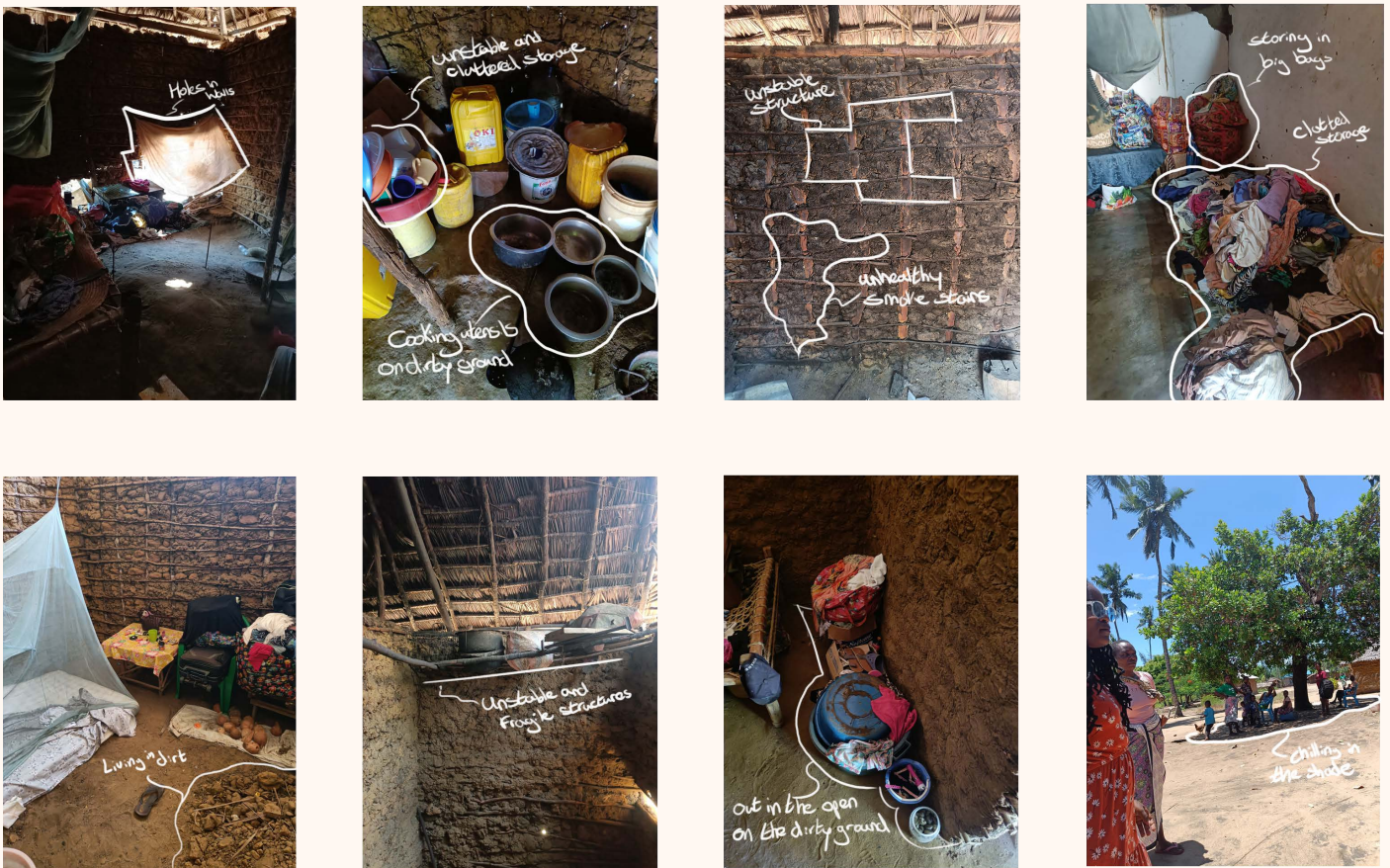


Figure 32: Observation insights

The observational studies at local homes in Watamu provided deeper insights into these problem areas. We observed that the residents indeed spend most of their day in the shade, with improvised seating made from used tires and wooden benches. While the house is only used for sleeping and storing their possessions. However, the inadequate structural elements of the houses, holes in walls, and unstable foundations contributed to an unsanitary living environment. It was found that there were no or very fragile storage possibilities which led to an overall messy feel in the house perceived by the home-owners. Next to that the ground floor and mud walls contribute to a lot of dust and dirt everywhere. Key takeaways underscored the urgent need for improved cleaning methods and structural enhancements to improve overall living conditions (see figure 32).

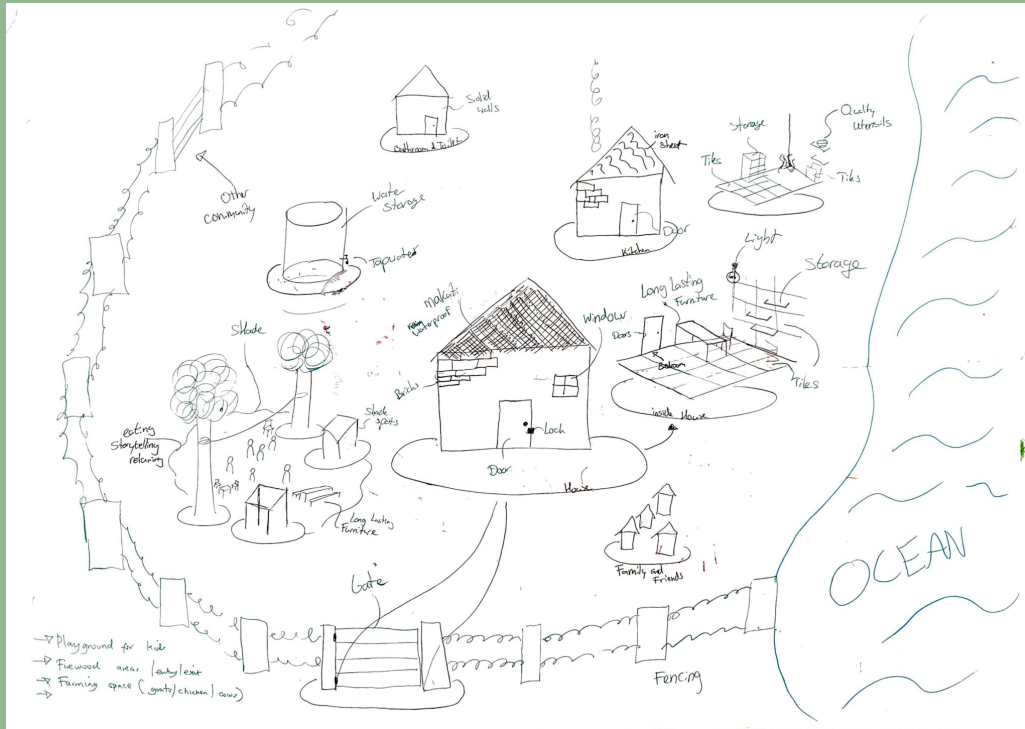


Figure 33: Ideal situation drawing made with the end users

Engaging the local community in creative sessions at EcoWorld yielded a collaborative exploration of solutions to address these challenges. Participants visualized their vision for a cleaner, more comfortable, and safer home, emphasizing the importance of easier cleaning methods, enhanced storage options, and structurally improved housing. Figure 33 shows an overview of all the insights derived from the session highlighting these problem areas with idea possibilities for an ideal context.

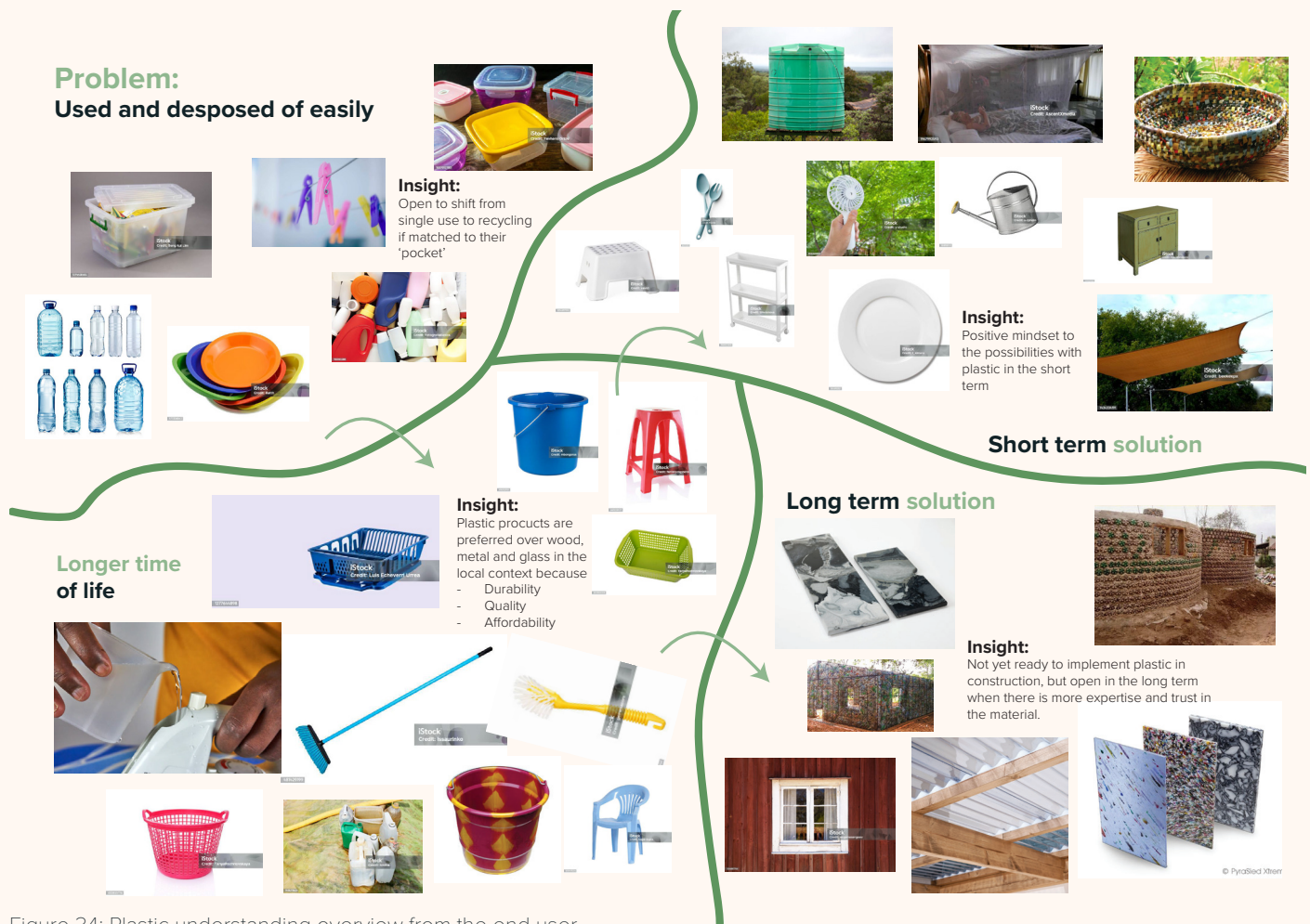


Figure 34: Plastic understanding overview from the end user

The next session focused on exploring the potential of plastic waste as a resource for sustainable solutions (see figure 34). During the session, the participants were able to get hands-on with plastic waste and plastic products (see figure 35). It was found that they value good quality in end-products and that the brick, but also the recycled coaster felt durable to them, and they understood that from plastic waste quality products can be made. When shown the initial plastic waste; plastic bottles, 3D printed waste material, PVC canvas and a plastic coffee cup, they immediately saw the potential of the material (coming back to that repair and reuse mindset). They see it as a functional material that they use all the time and after showing the upcycled products they understood the potential and advantages of using this material. Next to that, the participants created an overview of the plastic waste problem from their perspective.

The main takeaway was that participants exhibited a positive attitude towards recycled plastic products as opposed to alternative materials, recognizing the durability and potential for long-term use.

While hesitant to embrace plastic in structural elements of their homes, they expressed openness to implementing recycled plastic in other household products.



Figure 35: Insights on plastic perception



Figure 36: Ideation insights

The design sprint ended with an ideation session, where participants generated ideas to improve their living conditions across the identified problem areas. The practical mindset of the participants showed the importance of simplicity and functionality in the design solutions. From this session, five distinct idea directions emerged: Tiles, Storage Possibilities, Furniture, Shelter Places, and Cleaning Utensils as seen in the post-its in figure 36. In another exercise, the participants were asked to make a collage of plastic products that they would like in their homes to improve their living conditions. In figure 37 the results can be found that also highlight the desirability of these 5 idea directions from the end user's perspective. These directions created by the local community are used for further exploration in the next design sprints.

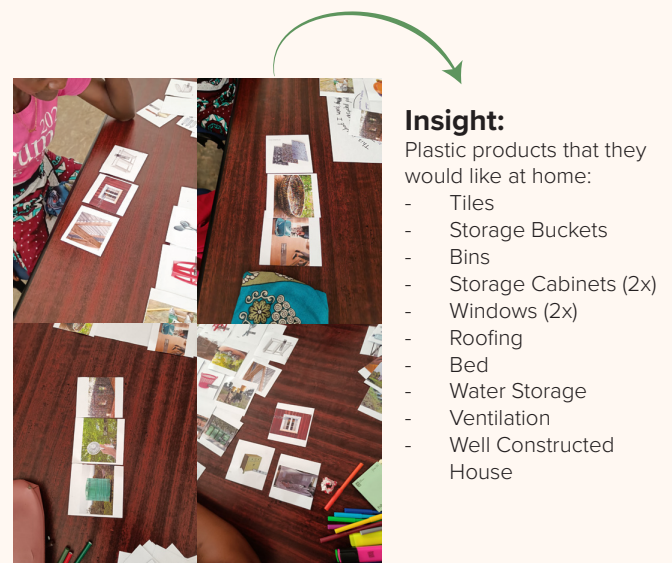


Figure 37: Collage insights

Key takeaways from Design Sprint 2:

- 4.5 Addressing shelter comfort, household cleaning, and home safety as the main problem areas in house.
- 4.6 Users foster a positive attitude and understanding of plastic's potential.
- 4.7 There is an acknowledgment of the possibilities of recycled plastic over other alternative materials.
- 4.8 Exploring five distinct solution directions for further development; Tiles, Storage Possibilities, Furniture, Shelter Places, and Cleaning Utensils.
- 4.9 Community preference for practical and functional design solutions.



Figure 38: Photo of the creative session in progress

4.4 Design Sprint 3: Solution Convergence

Design Sprint Approach:

This third sprint marks the initial steps towards convergence during the field research. The framework developed in weeks 1 and 2, along with the comprehensive criteria list from both the company and end-users, serve as guiding tools for decision-making toward the final solution direction. Progress is validated with all stakeholders involved in the process, and the solution space is explored in-depth through a co-creation session.

Design Goal:

The goal is to collaboratively choose the most promising solution direction with all stakeholders involved and further develop this solution space.

Methods Employed:

A third creative session, involving four local Kenyan women, was conducted to review all generated content from the previous two weeks. Together with the participants, the results were validated, and a direction was chosen utilizing the criteria list, framework, and session activities. Within the selected direction, the session facilitated a deeper understanding of the solution space through a more focused round of ideation and reformulation of the problem statement.

Validation and Next Steps:

The sprint concluded with a chosen direction agreed upon with the participants, which is taken for prototyping in the final design sprint. This choice underwent validation with the company post-session to ensure alignment with their perspective and future goals.

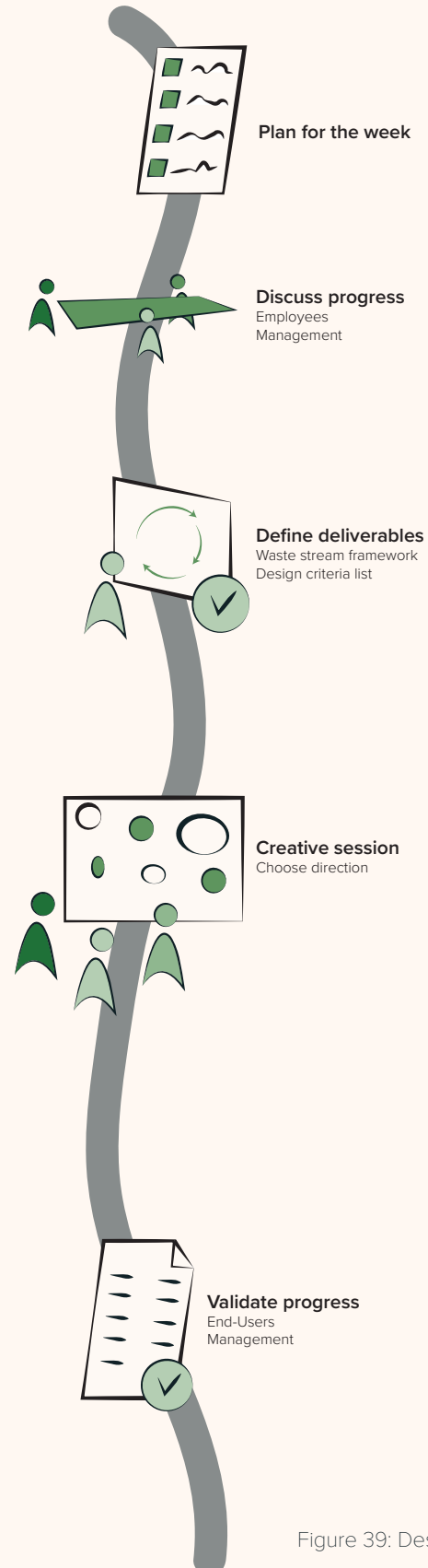


Figure 39: Design Sprint 3

After finalizing the framework with input from both the company and end users, a set of criteria was established to guide our decision-making process. This prioritized list, detailed in the figure on the right, is organized into social, environmental, and company impact themes. Social impact emerged as the primary criteria theme, given its significance in enhancing the product in the use stage and creating opportunities across various other stages of the product lifecycle, such as end-of-life considerations and circular design. Given EcoWorld's focus on empowering local women and youth through plastic waste initiatives, emphasis was placed on social and environmental impact over company impact.

To narrow down the focus, hygiene in home was selected as the primary problem to address. The analysis shown in figure 40,41 and 42 revealed that hygiene in the house scored highest overall among the three criteria themes. This decision was influenced by the understanding that comfort in shelter products face challenges surviving harsh outdoor conditions, necessitating materials other than plastic for durability and safety. Furthermore, the community's current mindset does not favor implementing plastic in structural housing elements, while the safety in home theme focuses primarily on improving the structure. Therefore, the direction towards hygiene in house was chosen.

- Social impact**
- S1 Create products that offer significant social benefits to end-users in comparison to the current portfolio.
 - S2 Empower the local community by involving them in the design process and providing opportunities for skill development and inclusivity.
 - S3 Prioritize local production and sourcing of materials to support the regional economy.
 - S4 Ensure affordability of products in comparison to the existing products to promote the adoption of sustainable practices.
 - S5 Ensure that product designs align with and respect the cultural context of the target audience, incorporating elements that resonate with local values, traditions, and aesthetics.
- Environmental impact**
- E1 Implement improvements in critical stages of the waste cycle to close the waste loop and grow towards a circular practice.
 - E2 Ensure that products have a targeted lifespan of one year and are designed for easy recyclability at the end of their use.
 - E3 Use only plastic waste in the product design to promote environmental sustainability.
 - E4 Design products with an emphasis on easy reparability to extend their lifespan and minimize waste generation.
- Company/business impact**
- C1 Design products that generate increased financial value for the company in comparison to the current portfolio.
 - C2 Enhance the awareness of Ecoworld's environmental efforts through the product design.

Figure 40: Hierarchical criteria list

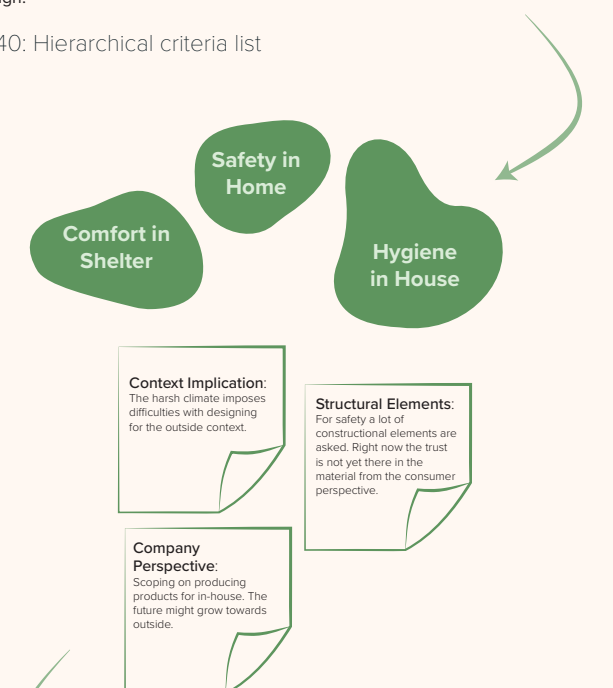


Figure 41: Clustered opportunity spaces

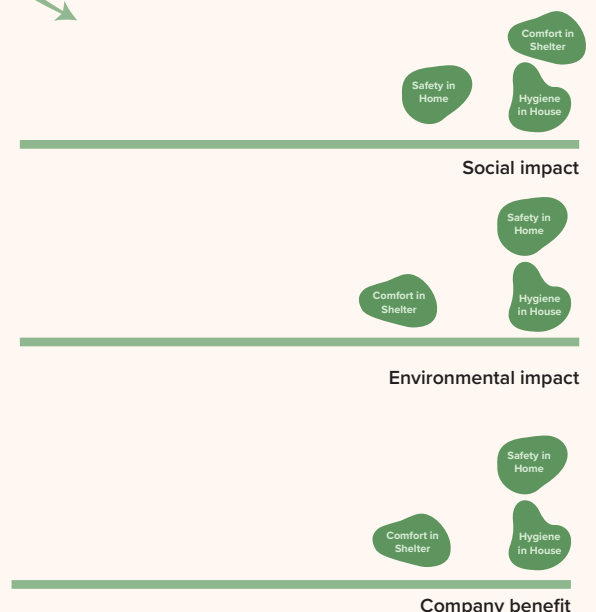


Figure 42: The clustered on an impact scale

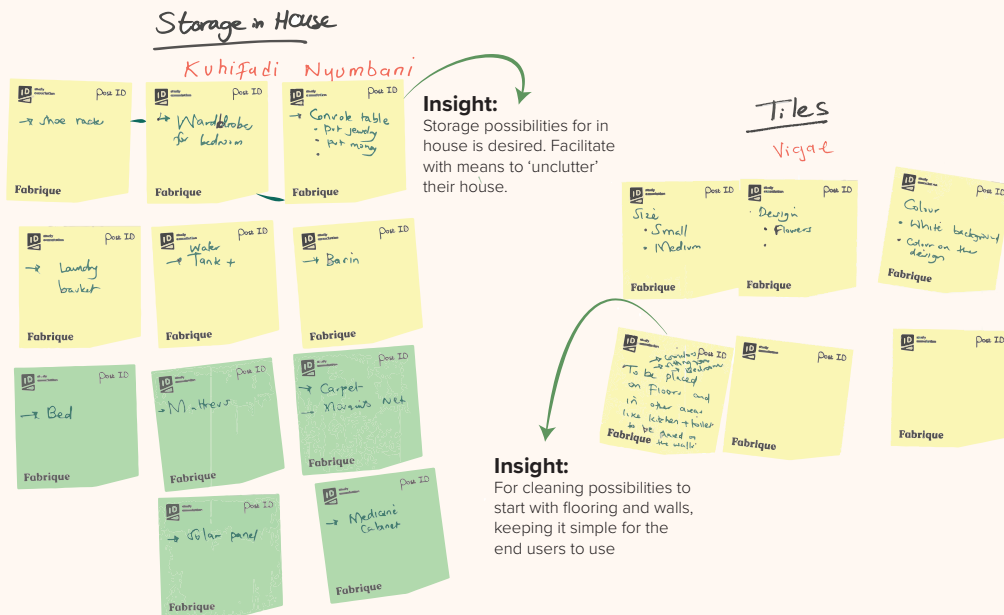


Figure 43: Insights from the second ideation session

This research will concentrate on enhancing hygiene within local homes in Watamu, with a focus on developing tiles, storage solutions, and cleaning utensils. These idea directions were found during the first 2 creative sessions. Validation of this choice was obtained through the final creative session with the community and the company. During this session, it became clear that participants have a practical mindset, drawing inspiration from existing resources and practical solutions (see figure 43). This confirmed the importance of prioritizing functionality and simplicity in implementing designs within their homes.

From the input of the final creative session, 3 concept directions were drawn and shown in Appendix C.

These directions are made at the same level to be able to assess them using the Harris Profile method, a method to choose a final direction. The possibilities with this direction are shown, and a visual moodboard to portray the vision of the direction. A rough estimation of the costs is given based on market research and online information about energy costs. Lastly, the impact and the possible pitfalls are pointed out to look into further.

Using the Harris Profile method (van Boeijen, 2020), these ideas were evaluated against the established criteria, with the results shown in figure 44 with the clarification of the scores in Appendix D. Based on this assessment, the decision was made to proceed with creating storage facilities in local homes in Watamu, but keeping the concept direction of tiles in mind because of the potential in the future.

Social impact	
S1	Create products that offer significant social benefits to end-users in comparison to the current portfolio.
S2	Empower the local community by involving them in the design process and providing opportunities for skill development and inclusivity.
S3	Prioritize local production and sourcing of materials to support the regional economy.
S4	Ensure affordability of products in comparison to the existing products to promote the adoption of sustainable practices.
S5	Ensure that product designs align with and respect the cultural context of the target audience, incorporating elements that resonate with local values, traditions, and aesthetics.
Environmental impact	
E1	Implement improvements in critical stages of the waste cycle to close the waste loop and grow towards a circular practice.
E2	Ensure that products have a targeted lifespan of one year and are designed for easy recyclability at the end of their use.
E3	Use only plastic waste in the product design to promote environmental sustainability.
E4	Design products with an emphasis on easy repairability to extend their lifespan and minimize waste generation.
Company/business impact	
C1	Design products that generate increased financial value for the company in comparison to the current portfolio.
C2	Enhance the awareness of Ecoworld's environmental efforts through the product design.

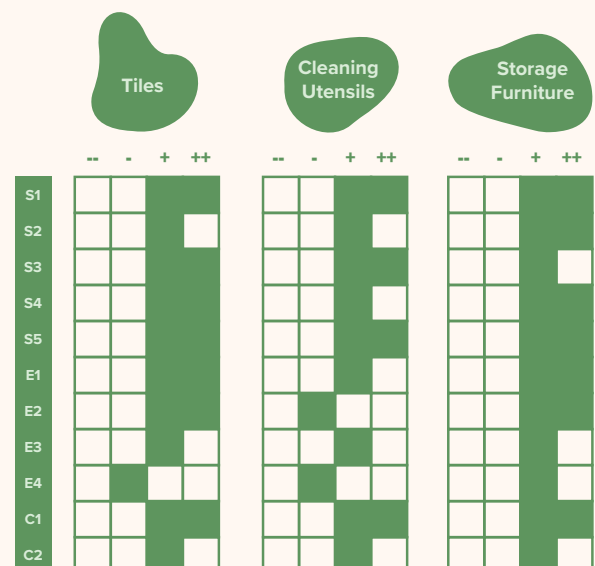


Figure 44: Harris Profile based on the criteria list

Key takeaways from Design Sprint 3:

- 4.10 Prioritize cleanliness in housing, focusing on tiles and storage solutions.
- 4.11 Recognize the significance of hygiene in Kenyan culture and its crucial role for homeowners' health and status.
- 4.12 Ensure that the product is accessible in function, material, and implementation, with simplicity as the guiding principle.



Figure 45: Photo of the ideation session in progress

4.4 Design Sprint 4: Prototyping

Design Sprint Approach:

The final sprint serves as the culmination of all the work generated from the previous sprints. At this point, there exists a comprehensive understanding of the problem area from various stakeholders' perspectives. Together with the local community, a solution space was created and selected towards creating storage possibilities in house. This sprint concentrates on crafting tangible prototypes to be tested in the homes of end users, gathering feedback on the physical products, and co-validating the final step of the field research.

Design Goal:

The goal is to refine the most promising ideas and co-validate the solution direction in collaboration with end users.

Methods Employed:

EcoWorld employees were involved in designing the mold of the prototype, testing various manufacturing techniques, and testing them at the facility. Different mold types were experimented with to create desired shapes of optimal quality. To ensure the highest quality, various types of plastic were tested, with employees' expertise used for material choices. A final mold was collaboratively crafted with a local welder, demonstrating local feasibility in Watamu. Various products were crafted with different materials for presentation to end-users. These prototypes were explained in context and placed in real-life scenarios to gather insightful feedback.

Validation and Next Steps:

The final mold was created and validated in collaboration with employees and end users within their real-life context. A manufacturing technique was selected, suitable for local implementation with opportunities for refinement. Material selection was guided by both employee expertise and end-user preferences, culminating in a final concept direction for the next phase of research in the Netherlands.

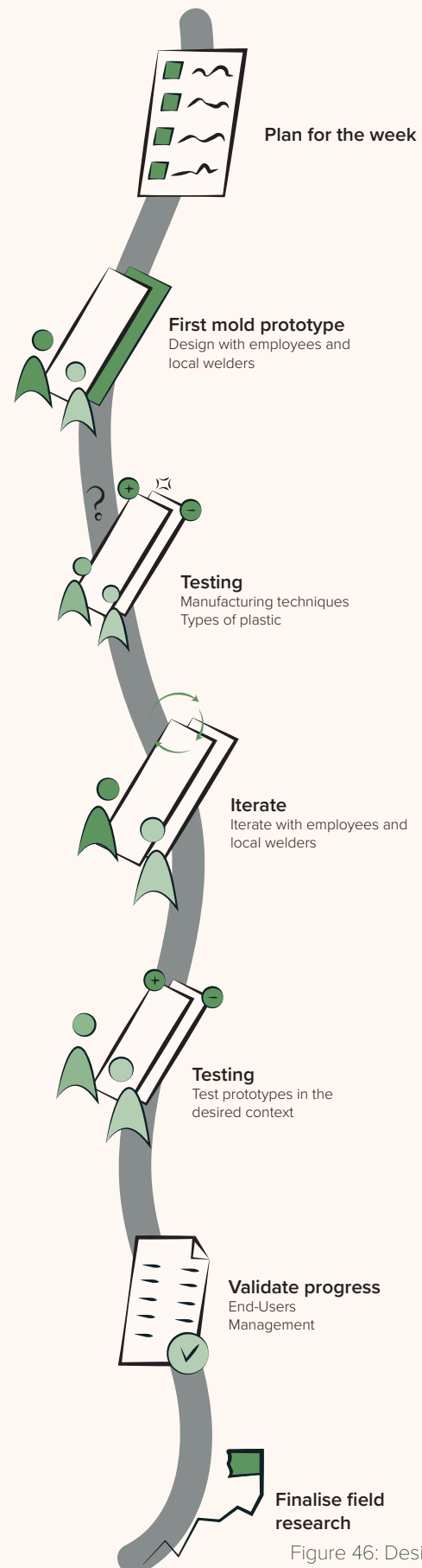


Figure 46: Design Sprint 4



Figure 47: Insights from prototyping together with EcoWorld employees

During the first week at EcoWorld, an opportunity to introduce new technologies to the company was identified, with sheet press technology emerging as a promising option. This technology offers significant potential for processing plastic waste and affords considerable flexibility in product design, found while interviewing a Precious Plastic employee. With new grants on the way, EcoWorld expressed keen interest in exploring these innovative techniques. In collaboration with EcoWorld employees and a local welder, a prototype sheet press was created (see figure 47) using simple techniques to assess its feasibility and viability within the local context.

Upon testing, it became clear that adjustments were necessary to optimize the mold design and enhance pressure application during the process. Mechanical replication of a sheet press proved challenging.

The next iteration focussed on manually melting the plastic in a separate pan and pouring it into the mold, then applying pressure using heavy rocks. This approach showed promising results, successfully forming shelves and tiles. Notably, three shelves were produced using different types of plastic (PP, HDPE, and PET) to evaluate the different materials and their applicability.

Despite challenges such as limited space and quality control issues during manufacturing, the process demonstrated significant potential for locally producing high-quality products from plastic waste. Employees showed a very good understanding of the process and actively contributed to positively developing the manufacturing techniques, underscoring the feasibility of introducing such technologies at EcoWorld. Key takeaways from these tests highlight the feasibility, viability, and practicality of creating new products from plastic waste with minimal resources and costs.



Figure 48: Gathering feedback from the local end users

These prototypes were presented to the local community to get their response and feedback and to assess real-world applicability. The prototypes were held and mimicked into their intended use to show the look and feel at the homes. Community members expressed enthusiasm, particularly noting the sturdy feel and durability of the shelves. While initial hesitation towards using tiles for flooring was observed, due to the quality at this stage. However, there was a desire for the wall tiles. Feedback indicated a positive attitude towards purchasing shelves, with preferences for PP due to its lightweight yet sturdy nature. PET tiles were favored for wall applications, valued for their color and quality feel compared to HDPE, which was perceived as bulky. Envisioning the products in their homes, community members highlighted the potential for enhancing aesthetics and creating a more homely atmosphere, particularly with colorful shelves (see figure 48).

Key takeaways from Design Sprint 4:

- 4.13 Use PP for wall tiles and shelves, and PET for floor tiles and structural cabinet elements.
- 4.14 Emphasize color over dull grey and black for enhanced appeal and acceptance.
- 4.15 Prioritize tiles and storage solutions to foster a cleaner home environment.
- 4.16 Implement local production methods by melting plastic separately and pouring it into molds showing promising potential.



Figure 49: The end user testing the prototypes

4.5 Deepening the context research

From the key takeaways found during the field research a solution direction was chosen towards creating storage possibilities for local end users. This section deepens the research context focusing on understanding the hygiene needs in the local context as well as the functionality and safety needs from the end user's perspective.

4.5.1 Hygiene

As found, the primary concern that local residents aim to address in their living environment is the maintenance of cleanliness within their homes. Upon visiting these households, it became clear that inhabitants struggle with cluttered floors and the accumulation of dirt and dust. This initial issue is derived from a lack of furniture within the homes, leading to possessions scattered across the floor or stored in large bags. Consequently, there is a lack of organization and visibility of belongings, while the floor only makes these belongings more dirty. This introduces the second issue: the accumulation of dust and dirt within the homes. Because of the construction of houses using mud walls and floors, dust accumulates easily. Given the significant importance of hygiene within the local context, as previously established, residents try to maintain a clean environment through daily floor sweeping. Unfortunately, this effort proves futile due to inadequate facilities, underscoring the significant hygiene challenges faced by local communities. Addressing these two foundational issues is imperative as they serve as primary drivers in addressing household cleanliness moving forward.

4.5.2 Items to store

In the context of low-income households, there are primarily two categories of possessions: kitchen utensils and clothing. This project will center on offering storage solutions specifically for kitchen utensils, either within the house or in the kitchen area. The emphasis on kitchen utensils is derived from the observation that these items are found to be impacted by the dirt the most. Given that these utensils come into contact with food and even attract wild animals, improper storage poses significant health risks. Therefore, addressing the storage of kitchen utensils is crucial to solve these health hazards. Figure 50 shows the different kitchen utensils that can be found in local households.



Figure 50: Overview of the products that need to be stored

4.5.3 Safety measures

In addressing safety concerns for the design, it's important to recognize the poor structural condition of the low-income community houses in Watamu. Given this, it's advisable that the design is not wall-mounted but instead be a standalone product placed on the floor. This necessitates a sturdy and robust construction capable of accommodating multiple items. Safety considerations extend beyond structural integrity to usability, especially since both adults and children will be utilizing the product. Consequently, the design should feature smooth edges to prevent injuries and remain stable even when unevenly loaded. Additionally, to not encourage climbing and minimize animals attraction, some shelves need to be elevated. This measure also aids in keeping insects away from the storage facility. Implementing methods to elevate products off the ground can further reduce insect presence compared to the current scenario. Furthermore, it's imperative to consider the potential disintegration of microplastics over time, especially when reusing plastic waste. To prevent this, the product should be shielded from direct sunlight or minimize friction between the components, ensuring its longevity and reducing the release of microplastics into the environment.

Key takeaways from Deepening research

- 4.17 Hygiene is very important to the local end-users, while it is a form of status to them.
- 4.18 Hygiene in house is hard to maintain for end-users.
- 4.19 Most important issues to address are the cluttered floors and the accumulation of dust everywhere.
- 4.20 Reduce the amount of microplastics by avoiding direct sunlight and avoid intensive use.
- 4.21 A stable and stand-alone construction is imperative to make sure the concept does not fall when loaded or used.
- 4.22 The concept comes into contact with animals and children, this should be addressed in the concept development.

4.6 Conclusion

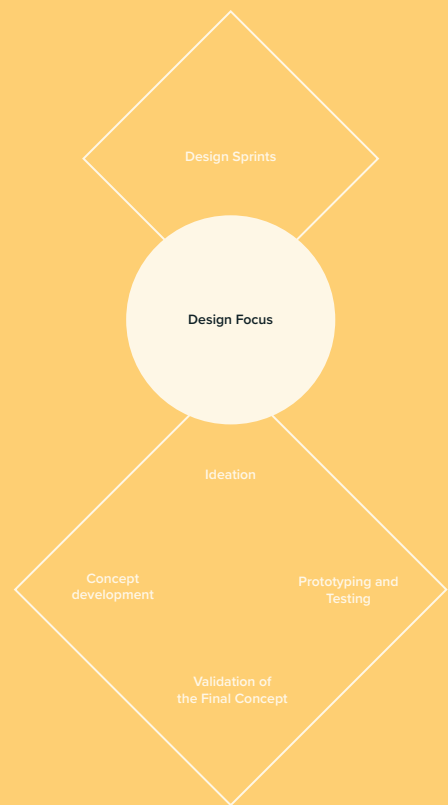
To conclude this phase of the project, opportunities for both user engagement and end-of-life considerations in the product life cycle have been explored, centering efforts on empowering the local community, particularly focusing on women and youth. EcoWorld employees have demonstrated a willingness to adopt new technologies and explore circular economy principles, which has sparked broader community knowledge about handling plastic waste.

Research has identified shelter comfort, household cleaning, and home safety as the main problem areas in local homes. Users have developed a positive attitude and understanding of plastic's potential, recognizing the possibilities of recycled plastic over other alternative materials. The community has expressed a preference for practical and functional design solutions, prioritizing cleanliness in housing. Tiles and storage solutions emerged as crucial, given the significant role of hygiene in Kenyan culture for homeowners' health and status. Ensuring accessibility in function, material, and implementation, with simplicity as the guiding principle, is essential. Specifically, PP will be used for wall tiles and shelves, and PET for floor tiles. Additionally, emphasizing color over dull grey and black will enhance appeal and acceptance.

Prioritizing tiles and storage solutions aims to foster a cleaner home environment. The current living conditions in house are inadequate with cluttered floors and dust everywhere due to the mud walls and floors. This makes it hard to maintain a clean living environment, while this is very important to the end-users. Implementing local production methods, such as melting plastic separately and pouring it into molds, has shown promising potential. This phase has laid a solid foundation for sustainable, socially impactful design solutions, with promising technological feasibility and strong community involvement.

Integrating the local end user has been crucial for gathering valuable insights throughout this phase of the project. Immersing in the local context has clarified the possibilities and limitations in terms of safety and implementation possibilities. Involving the end users in the design phase has broadened their perception of plastic waste, helping them discover its potential and understand the importance of proper handling. This engagement has highlighted the need to spread knowledge about plastic waste among local communities, this to ignite the economy and raise awareness that plastic is a valuable resource in these developing countries.

The key takeaways and design requirements identified thus far will shape the design focus addressed in the next chapter. The data collected, along with the direction established in collaboration with local end users, will be carried into the next design phase, concentrating on further refining the ideas toward a final concept that fits in the local context and can ignite the emerging local recycling economy.



05

Design Focus

This chapter provides an overview of the key takeaways from the previous chapters, as well as the design requirements necessary to create a focused direction for the design phase. The key takeaways from the previous chapters are organized into actionable points that inform the concept design. These actionable points culminate towards design requirements that establish a design goal, serving as a foundation for the next phase. This chapter sets out the parameters for the following design phase.



Figure 51: A generative activity during a creative session

Chapter Overview

- 5.1 Clustering Key Takeaways towards action
 - 5.1.1 Shift towards CE
 - 5.1.2 Create a greater understanding among end users
 - 5.1.3 Actions to involve the stakeholders
 - 5.1.4 Fit in the cultural context
 - 5.1.5 Additional Advice
- 5.2 Design Requirements
 - 5.2.1 Fit in the local context
 - 5.2.2 Functionality
 - 5.2.3 Circular Design
- 5.3 Design Goal

5.1 Clustering Key Takeaways towards action

5.1.1 Shift towards CE

- 1.1 Incorporate end users' perspectives throughout the design process to understand their needs, ensuring the resulting products align with their culture.
- 1.2 Design products to recapture resources, components, or materials at the end of their lifecycle to reintegrate them back into the production process.
- 1.3 Broaden the product portfolio to expand knowledge and facilitate a more comprehensive approach to circular design.
- 1.4 Integrate PP (and PET) into product design with a focus on recyclability, durability, and ease of recovery to promote circularity.
- 1.5 Develop products that actively contribute to social well-being, such as creating job opportunities, fostering community engagement, or addressing social inequalities.
- 1.6 Increase circularity by designing for remanufacturing, refurbishment, durability or repairability.

5.1.2 Create a greater understanding among end users

- 2.1 Communicate and show the reliability of materials to instill confidence in their use and the possibilities of recycling.
- 2.2 Share knowledge about the circular economy within communities to empower informed decision-making and encourage participation in sustainable practices.
- 2.3 Engage with materials firsthand to showcase their versatility and possibilities to inspire innovative design solutions
- 2.4 Implement strategies to improve waste management, focusing on recycling, reuse, and proper collection.

- 2.5 Develop a structured framework to effectively communicate the principles and benefits of the circular economy to stakeholders, fostering understanding and support for sustainable practices.

5.1.3 Actions to involve the stakeholders

- 3.1 Prioritize local manufacturing to foster a sense of community ownership over products.
- 3.2 Host talks and workshops within communities to align values, educate on circular principles, and encourage collective action towards sustainable practices.
- 3.3 Provide rewards or incentives for consumers to participate in circular behaviors such as recycling, repurposing, or returning products, reinforcing the value of closing the loop.
- 3.4 Create jobs through circular initiatives to engage individuals in meaningful sustainable work
- 3.5 Foster the growth of local SMEs focused on circular solutions, promoting innovation and community collaboration.

5.1.4 Fit in the cultural context

- 4.1 Design products that align with local cultural values around cleanliness and hygiene, ensuring they support and enhance household routines and practices.
- 4.2 Design products that meet the quality standards of the local end-users while keeping it affordable for low and middle income households.

- 4.3 Tap into the local repair mindset by designing products for reparability, empowering consumers to prolong product lifespans and reduce waste.
- 4.4 Design products that reflect the aesthetic preferences and traditions of the local community, enhancing their appeal and relevance.
- 4.5 Design products with a focus on inclusivity and accessibility to promote social cohesion.
- 4.6 Employ production methods and techniques that are familiar and well-established within the local context.

5.1.5 Additional Advice

- 5.1 Develop tile solutions tailored to the needs of middle-income households, enhancing cleanliness in their houses.
- 5.2 Grow towards the construction industry over time, based on the established trust in the material from the end-user.
- 5.3 Expand business operations and initiatives along coastal regions to spread knowledge, awareness and resources.



Figure 52: Child interacting during observations at local homes

5.2 Design Requirements

5.2.1 Fit in the local context

- 1.1 **Simplicity:** The design should be simple, enhancing user comprehension and usability
- 1.2 **Stationary:** The product should be stationed on the ground
- 1.3 **Local Production:** The product should be able to be produced locally with a sheet press
- 1.4 **Affordable:** The product should not cost more than 2000 Kenyan Shillings
- 1.5 **Recognizable:** The product should be an eye-catcher in the house, resonating with cultural aesthetics.

5.2.2 Functionality

- 2.1 **Practical:** The product should be straightforward and practical in use to the local context
- 2.2 **Show Content:** The product should show what is stored inside
- 2.3 **Kitchen Utensils:** The product should be able to store kitchen utensils such as basins, pans, cups and plates
- 2.4 **Self-Sufficient:** The product should be able to stand on its own

5.2.3 Circular Design

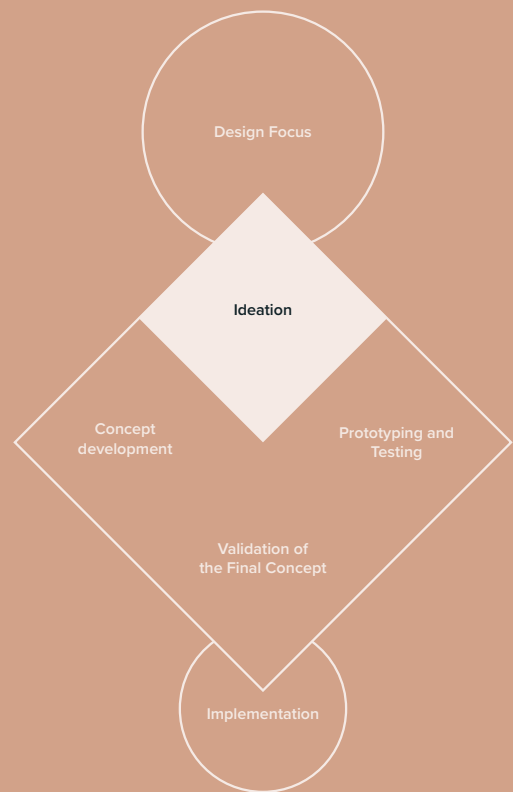
- 3.1 **Modular:** The product should be modular, with easy disassembly possibilities
- 3.2 **Repairability:** The product should be made to be easily repaired
- 3.3 **Ease of Assembly:** The product should have as less as possible permanent connections
- 3.4 **Durable:** The product should last for more than 1 year
- 3.5 **Local Recycled Waste:** The products should be made from local PP and/or PET waste
- 3.6 **Incentive:** The product should give an incentive to recycle at the end of life

5.3 Design Goal

Based on the key takeaways and the design requirements a design goal for the next phase of the project was defined. This design goal focuses on a practical and functional design that fits in the local context, while taking a circular design approach. This way the design goal comes back to the challenges mentioned at the beginning of this research.

“Design a **recycled plastic-based, locally manufactured product** to **store personal possessions** which **improves and facilitates local Kenyan household cleanliness** through its **straightforward usage, affordability, and minimalistic design**”





06

From Ideas to a Future Concept

Building on the design focus established from field research, media, and literature studies conducted in the research phase, the design phase begins. This chapter outlines the initial steps in translating this focus into ideas that evolve into concept directions. The aim is to generate ideas across the various clusters identified in the previous chapter. Drawing inspiration from the field and experts to set up the ideation phase. The ideation session included multiple design and choosing methods to create ideas. These ideas were then evaluated into three concepts, which are further detailed and prototyped in this chapter. Each concept is assessed against the design requirements set in the previous chapter, incorporating feedback from end users in Watamu. This process culminates in selecting a final concept direction, which will be developed in the next chapter.



Figure 53: Prototyping together with local employees

Chapter Overview

- 6.1 Inspiration for Ideation
 - 6.1.1 Design for Disassembly
 - 6.1.2 IKEA
 - 6.1.3 Expert brainstorm
- 6.2 Ideation Session
 - 6.2.1 Ideation
 - 6.2.2 Rapid Prototyping
- 6.3 Towards a Final Concept
 - 6.3.1 Choosing methods

6.1 Inspiration for Ideation

This section describes how various inspirational sources relate to the design focus established in the previous chapter. These sources provided ideas for incorporating a hands-on approach and integrating a circular design approach. Additionally, expert interviews offered deeper insights into cabinet design, on how to design a structurally sound product.

6.1.1 Design for Disassembly

As part of the circular design approach during the design phase, the integration of a design for disassembly strategy is taken as inspiration. This approach facilitates end users in slowing down the loop by making it easier to disassemble the product at the end of its life, ensuring proper disposal. Additionally, it promotes modularity, allowing components to be easily separated and substituted once they reach their end of life, such as shelves in this case.

This approach follows specific guidelines that can be implemented in the product design. The first guideline is the level of separation, focusing on an assembly process with minimal steps to ensure comprehensibility for users. Creating simple assembly sequences and focusing on the types of connections makes the design accessible and modular. By minimizing permanent connections, the product's end-of-life considerations are addressed, enabling the substitution of elements. This also taps into the DIY mentality of the end users, with assembling, disassembling, and the versatility of this approach.

6.1.2 IKEA

Another source of inspiration is IKEA, a company known for its focus on easy assembly sequences for end users, particularly in the storage market. IKEA's approach to building storage facilities and their assembly process has been a significant influence throughout the design phase. Their simplistic designs and user-friendly assembly manuals are known for being comprehensible and accessible.

Their hands-on approach with regards to a DIY cabinet fits very well in the design focus that was established. Additionally, IKEA has made substantial strides in ensuring the safety of their cabinets. Although their solutions often involve connections to the wall, which is not ideal in the context of this research, their approach and expertise in safety measures are valuable and informative.

6.1.3 Expert brainstorm

A brainstorming session with woodworking experts was conducted to integrate their expertise into cabinet design. Their opinions on designing modular cabinets with fewer permanent connections were sought, and their insights were incorporated into the ideation session described in the next section. During the interviews, common pitfalls in cabinet design were discussed, with the primary advice being to keep designs simple and learn from existing methods. Additionally, Integrated Product Design Alumni were interviewed to gain a better understanding of providing strength in construction. During the brainstorming session, various ideas were explored on creating a solid structure using plastic sheet material without permanent connections. These insights were also integrated into the following ideation session. This collaborative effort resulted in the identification of multiple innovative joining mechanisms and potential machinery and tools for working with plastic materials.

6.2 Ideation Session

From the inspiration sources and brainstorming with experts and fellow designers, a final ideation session was held to combine these into potential solution directions. Utilizing methods from the Delft Design Guide, the session explored possibilities while considering the insights and constraints identified during the field research. The main insights from this ideation session are highlighted below.



Figure 54: Ideation insights

6.2.1 Ideation

The main insights shown in the visual (figure 54) highlight the most promising ideas from the ideation session. Some ideas are emphasized to demonstrate their relation to the design focus and the created clusters. These concepts show potential for engaging the end-user in hands-on activities and promoting a better understanding of circular behavior, along with options to slow down the resource loop.

The visual also presents learnings from the field research, featuring various ideas to ensure the product fits the local context and meets the needs of local end-users. These ideas serve as the foundation of the concept, aligning with the design focus. The next ideation session will concentrate more on the physical shape of the product.

6.2.1 Rapid Prototyping

Safety and trust in the structure are crucial for local end-users, who prioritize durability and functionality when purchasing household products. To ensure a safe and solid structure, research into joining techniques for the plastic sheets is necessary. This project focuses on a circular design approach, drawing inspiration from designing for disassembly to extend product life. Several joining techniques that avoid permanent connections while maintaining structural integrity were explored.

A brainstorm session was conducted to explore various joining possibilities together with industry experts. The most promising technique identified was sliding the different shapes into each other. This mechanism was tested with a low-fidelity prototype to evaluate its potential for constructing a solid structure. The tests revealed that while sliding connections can create a solid bond, they do not prevent tilting under load. Further refinement and testing of this joining technique was necessary to ensure the stability and durability of the final design.

A combination of sliders and a lashing strap was chosen to create a seamless and aesthetically simple shape that fits the local context. The lashing strap ensures safety and durability by holding the structure in place when loaded. It simplifies assembly, disassembly, and production compared to traditional bolts and nuts. The lashing strap allows for non-permanent joints, achieving modularity. Additionally, the practical, hands-on mindset of local end-users is considered, as the lashing strap is a familiar product often already in use in households. When the concept reaches the end-of-life, the lashing strap can be repurposed for various uses beyond this project.

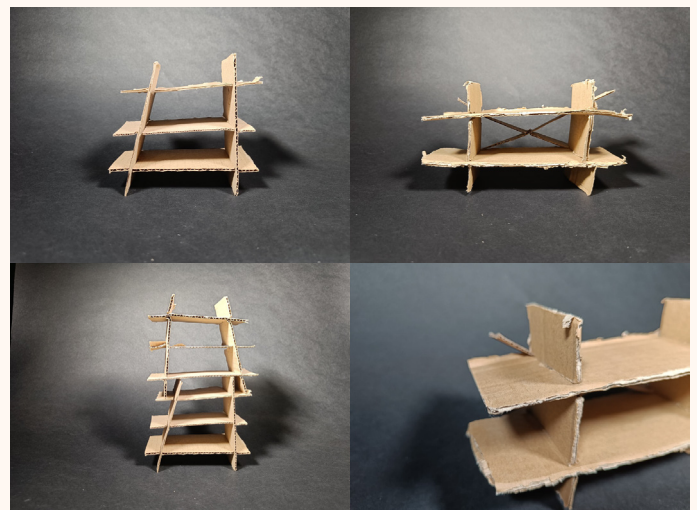


Figure 57: Lo-Fi prototypes

6.3 Towards a Final Concept

Based on the chosen shapes and joining mechanism, three concept pages were created. These pages are presented in appendix E. Each concept further details various elements of the design, ensuring they align with the design requirements. These concepts are developed with a focus on their suitability for the local context and their fit to a circular design approach. Additionally, they address the assembly and production process to ensure feasibility in the local setting. In this section, these concepts are evaluated against the design requirements to move towards selecting a final concept.

6.3.1 Choosing methods

To evaluate the different concepts, the design requirements outlined in Chapter 5 were used. Each concept was developed based on production aspects, contextual fit, and adherence to circular design principles, all of which are key components of the requirements. Additionally, functionality was considered, with particular emphasis on the user needs.

While a circular design approach is essential from the company's perspective, the fit in the context and functionality by end-users was prioritized. To select among the concepts, a Harris Profile was employed to score each concept, with detailed scoring available in Appendix F.

After scoring the concepts, it was found that both the TicTacToe (concept 3) and Square cabinet (concept 2) received equal scores. To make a definitive choice, feedback was sought from both end-users and the company, focusing on several key questions:

*Which shape best suits your local household?
Would you consider purchasing one of these cabinets when your current one requires replacement?*

Do you prefer self-assembly or receiving the cabinet pre-assembled?

Do you have confidence in the structural integrity of this shape and the use of lashing straps?

Fit in the Context	
C1	Simplicity: The design should be simple, enhancing the user comprehension and usability
C2	Stationary: The product should be stationed on the ground
C3	Local Production: The product should be able to be produced locally with a sheet press
C4	Affordable: The product should not cost more than 2000 Kenyan Shillings
C5	Recognizable: The product should be an eye-catcher in the house, resonating with cultural aesthetics
Functionality	
F1	Practical: The product should be straightforward and practical in use to the local context
F2	Kitchen Utensils: The product should be able to store kitchen utensils such as basins, pans, cups and plates
F3	Self Sufficient: The product should be able to stand on its own
F4	Show Content: The product should show what is stored inside
Circular Design	
D1	Modular: The product should be modular, with easy disassembly possibilities
D2	Design for Disassembly: The product should have as less as possible permanent connections
D3	Durable: The product should last for ore then 1 year
D4	Repairability: The product should be made to be easily repaired
D5	Local Recycled Waste: The products should be made from local PP and/or PET waste
D6	Incentive: The product should give and incentive to recycle at the end of life

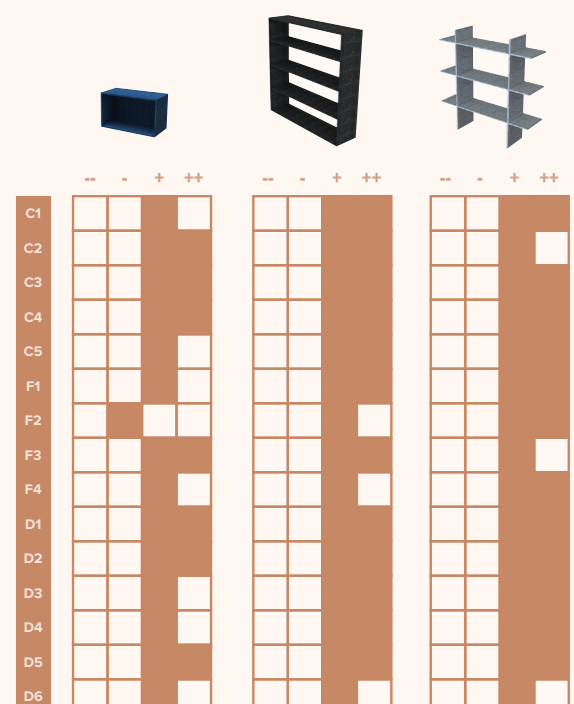


Figure 58: Harris Profile to choose based on the design requirements

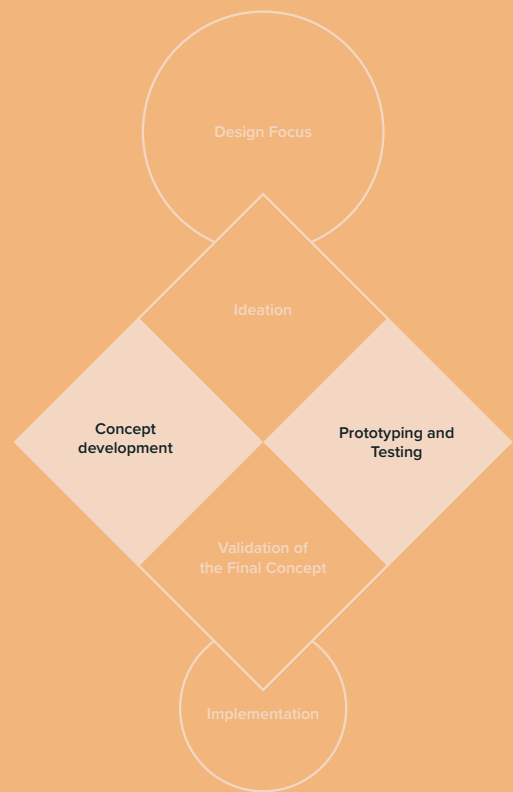
A questionnaire was drafted and sent to the end users, based on the questions previously outlined. This questionnaire was provided to a member of the EcoWorld management team, to whom the purpose and nuances were explained. This ensured that the concepts were communicated accurately and interpreted as intended. Eleven local community members participated in the interviews conducted through the questionnaire, with the EcoWorld representative present to address any questions or comments (see figure 59). The representative documented all feedback and questionnaire responses to communicate back. The questionnaire and the answers are shown in appendix G.

The responses revealed a clear preference for Concept 3 overall. While comments indicated minimal difference between Concepts 2 and 3, Concept 3 was particularly appreciated for its accessibility. Despite Concept 2 receiving higher marks for aesthetics, the accessibility and better fit of Concept 3 within the household were deemed more significant when looking back at the design focus. A notable comment highlighted the perceived sturdiness of Concept 2; this aspect will be incorporated into the further development of Concept 3. Additionally, it was found that users intend to primarily use the cabinet for kitchen utensils, though they also see its potential for use in other rooms. The average price community members are willing to pay is approximately 2000 ksh, and there is strong confidence in using lashing straps as a joining mechanism.

In conclusion, based on the Harris Profile and feedback from local community members, Concept 3, the TicTacToe shape, is preferred overall. The design requirements prioritize accessibility and household fit, where Concept 3 excels. Concept 2 is seen as more secure, this aspect will be considered in refining the final design of Concept 3.



Figure 59: Interviews held with local communities



07

Introducing the Final Concept

The final concept direction is a cabinet made from shelves that slide into each other, creating storage space for kitchen utensils. The shape of the design has been validated by the end users to ensure it fits within their local households and cultures. It has been tested against design requirements established during the research phase to ensure the functionality is tailored to the end users' needs, incorporating a circular design approach. This chapter will describe the development of the final concept, focusing on the most important interactions between end users and the product, as well as its fit within the design focus and created framework. Additionally, a final prototype will be made to test the joining mechanism and overall look and feel. The chapter will end with a final conclusion.



Figure 60: The final concept, prototype, in use

Chapter Overview

7.1 Interactions with the Concept

7.1.1 Safety

7.1.2 Hygiene

7.1.3 User Needs

7.1.4 DIY Approach

7.1.5 Fit in the Design Focus

7.2 Prototyping

7.3 Conclusion

7.1 Interactions with the Concept

In section 4.5.2, the primary use of the storage facility for kitchen utensils was described. However, other factors such as safety and hygiene, as well as the fit to the user needs and the DIY aspect, are crucial in finalizing the concept direction. This section dives deep into these aspects of the design.

7.1.1 Safety

Safety is a key consideration in the design, particularly to prevent tipping over, especially with the two-legged shape currently proposed. The cabinet will be primarily used by women in the kitchen, but children also have access, presenting a risk of climbing. Another concern raised was the risk of the cabinet tipping if bumped into. To address this, the cabinet can be dug into the ground, a familiar construction method for local community members who live on dirt floors and use similar techniques for building walls. This ensures the cabinet is stable without needing to be mounted on the weak structures of existing houses (see figure 61). However, to ensure the cabinet is securely fastened, it can be mounted to the wall. The design includes round holes for threading a lashing strap around the structure. These holes can also accommodate a wire, rope, or another lashing strap for wall mounting. Figure 62 illustrates this mounting method, providing additional security to prevent tipping over. For middle-income households with solid walls, mounting options like those used by IKEA can be explored also using these holes. Ensuring the shelves are 30 cm wide minimizes the risk of items falling out, accommodating general pans and basins, which are often the largest items that need to be stored.

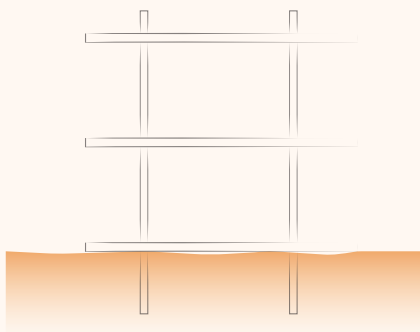


Figure 61: Digging in the concept

7.1.2 Hygiene

The design's impact on household hygiene in Watamu is significant. The biggest hygiene issues are the accumulation of dust due to mud walls and floors, along with cluttered floors. The cabinet's smooth, washable plastic finish facilitates easy cleaning and keeps items off the ground and away from mud walls, reducing dust accumulation. Shelves are elevated to prevent insects and animals, like chickens, from reaching stored items. To further prevent animals to reach the bottom shelf, chicken wire can be used to stop animals entering the cabinet. This wire can be put around the bottom layer of the product. Overall, the cabinet improves cleanliness by keeping items off the ground, reducing exposure to dirt, and minimizing the risk of insect and animal contact.

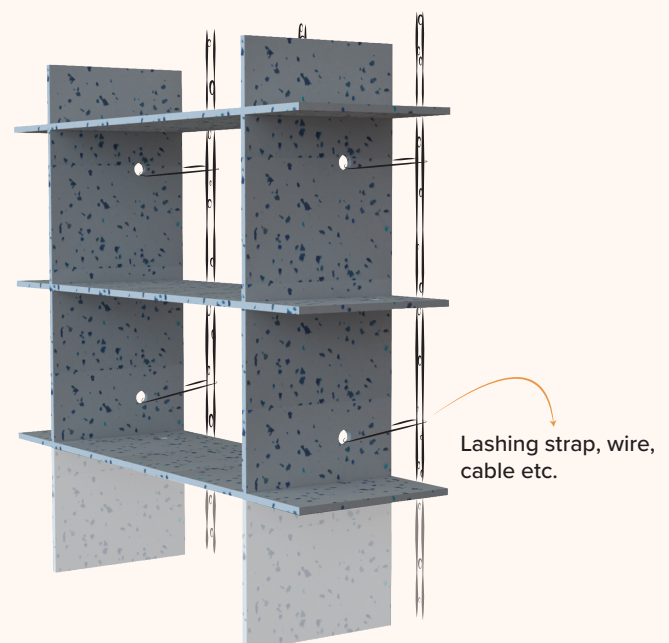


Figure 62: Attaching the concept to the wall

7.1.3 User Needs

Affordability, next to hygiene and safety, is another crucial need, with end users indicating a willingness to pay around 2000 ksh. The cost of 2000 ksh, roughly equivalent to 14.50 euros, represents about 30% of a household's monthly income in Watamu. This significant expense underscores why the initial product needs to be a familiar and recognizable item. Currently, end users have expressed that while they lack the funds to purchase entirely new furniture, they can afford to replace existing items. Hence, a cabinet was chosen for its immediate familiarity. Households are willing to save for durable and affordable products, making this cabinet a feasible option despite the substantial savings required. It will not be an impulse buy, but rather a considered investment in their household.

However, quality and durability is the most important aspect to a product for the local end users, even if it comes at a higher price. The use of plastic waste and a sturdy structure ensures quality as shown by other companies in the market that are also taking this approach, and the production costs are significantly lower than 2000 ksh (see appendix E).

This concept design stands out as a competitive alternative in the market, primarily due to its lower pricing. While alternative cabinets are sold for around 3000 Ksh, price is not always the main concern for end users. Therefore, extra emphasis is placed on the product's durability in daily use. In the next phase, the prototype will be tested for strength and durability to ensure it is a long-lasting product compared to wood, the common alternative.

One key aspect of durability is the material difference; in the sea climate, plastic proves to be more durable than wood as stated by local manufacturers in Watamu. Additionally, the product's overall meaning and fit within the local context offer significant advantages. The involvement of the user in both the initial use and end-of-life stages ensures that the concept aligns with local cultural values. The preferred shape fits well in current households, offering accessibility and clear visibility of contents. The cabinet's versatility and modularity ensure it accommodates various sizes and quantities of items, aligning with user needs identified throughout the research.

7.1.4 DIY Approach

To engage the practical, hands-on mindset of the end user, the cabinet is designed for DIY assembly. An easy-to-understand assembly manual is provided, requiring minimal tools. This approach supports the creation of local SMEs, which can assemble and sell the products, creating jobs and keeping production costs low. EcoWorld can sell unassembled packages with easier transportation and reduced production costs, while local SMEs handle assembly and retail.

Manual

The assembly manual, shown in appendix H, is designed to be straightforward and easy to apply in the local context. The concept uses minimal tools and no permanent connections, ensuring easy disassembly at the end of the product's life. The manual shows the assembly process of the concept, which in a reverse way is the disassembly process as well. The manual is made with very easy to understand drawings, that indicate the different components. A step by step walkthrough is shown to make sure that the assembly process is done in the correct way.

7.1.5 Fit in the Design Focus

The concept aligns with the design focus by using local plastic waste, primarily PP, and developing local knowledge through new manufacturing and finishing technologies. It builds trust in the material among end users and encourages proper waste management. The production process involves local stakeholders, creating jobs by outsourcing the retail of the products as well as introducing new techniques that require more manufacturers at EcoWorld. The development of a buy-back service incentivizes proper waste management and spreads knowledge amongst end users (see figure 63).

The design addresses household cleanliness through a product made from recycled local plastic waste, maintaining simplicity, accessibility, and adaptability as described in the design goal. The repair aspect, taps into the hands-on mindset of local people in Watamu who get more involved in the design process in this way.

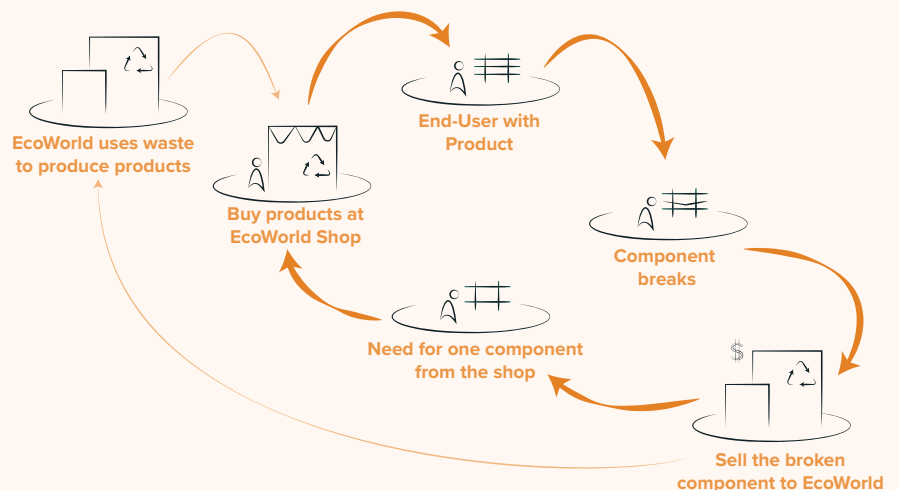


Figure 63: Buy back scheme

Throughout the design process the product-in-use phase was emphasized, involving end users to create social value through products that address current local struggles. The concept also focuses on the end-of-life phase, proposing a buy-back service for used plastic products. Using a single type of plastic waste (PP) simplifies remanufacturing, providing EcoWorld with low-cost raw materials and offering end users proper waste management and financial incentives. The concept also addresses other framework phases by using local plastic waste and fostering expertise within EcoWorld by exploring new strategies beyond mere recycling like remanufacturing, increasing the circular approach at EcoWorld.

Including this manufacturing technique contributes to slowing down the resource loop as well as the repair aspect of the concept and its physical and emotional durability. Especially the emotional durability is achieved by the close contribution of the end-user and the hands-on approach it takes.

The foundation and physical shape of the concept align with the framework and meet all criteria established with stakeholders at each phase of the circular product life cycle. Additionally, it addresses the overall design focus by considering the different clusters and design requirements. The next section will explore the feasibility of the concept through prototyping.

7.2 Prototyping

A prototype was built from this concept to test the joining mechanisms and design shape. The prototype measures 700x700x250 mm with a shelf thickness of 12 mm, matching the planned thickness of the plastic shelves. This prototype allows for testing usability, structural integrity and provides a tangible model for end-user and expert feedback.

The initial prototype demonstrated that the concept can be constructed from sheet material, using a wooden sheet in this case. A laser cutter was used for this prototype, which can be substituted with a router for plastic sheet material. This process was found to be very quick and easy once familiar with the different techniques. The use of a lashing strap was tested and significantly improved the concept's structural integrity, making it more stable and rigid. This mechanism, trusted and recognized by end-users in previous interviews, was thus confirmed for the design.

The safety aspect of the concept was also tested. The prototype was embedded in the ground and proved more stable and sturdy under heavy load or impact. The prototype was embedded to the same proportion as the actual concept, leading to a recommendation to dig it 250 mm into the ground.

The first prototype showed the desired shape was functional for storing kitchen utensils. However, the asymmetrical shape caused some confusion during assembly and it was unclear which part needed to be embedded in the ground. One side overhang was made larger, which invited more items on that side, whereas an even proportion is desired for safety.

Besides these usability tests, experts were interviewed on the structural integrity of the concept. While the lashing strap improved rigidity, the concept's behavior when made of plastic under load was not yet tested.

Interviews with Frans Taminau from UniBrick and IPD alumni provided key insights, leading to an iteration on the sliding slots to prevent bending and the introduction of holes instead of slots for threading the lashing strap. These holes will improve production time due to their easier manufacturing process. They are also moved back to 1/3rd of the width of the shelf to be less in the way of the products put on the shelf. Figure 64 presents the prototype insights. To fully validate the structural integrity, constructing a shelf from plastic for load testing is recommended, which will be addressed in the next chapter.

With insights from usability tests and expert interviews, a final prototype was built. This prototype demonstrated significant structural integrity and feasibility, enabling it to be sent to EcoWorld for final feedback. The prototype was filmed and photographed in use to provide end users and the company with a tangible product while being remote. This prototype will be used to test the concept's feasibility, viability, and desirability from the perspective of the end users and the employees of EcoWorld. The next chapter will present key takeaways from this final test towards a final concept evaluation.

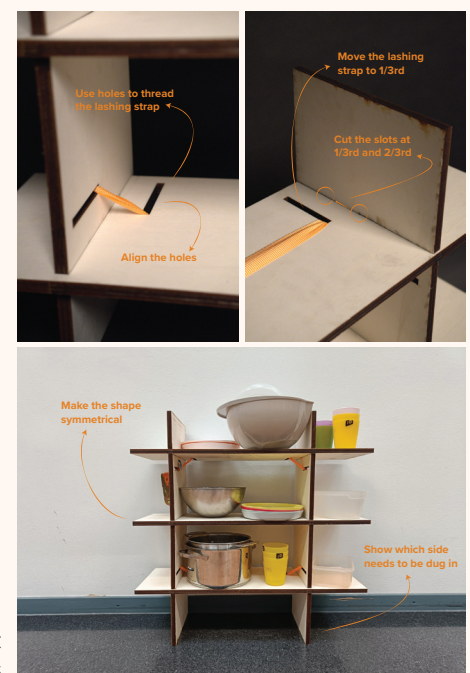


Figure 64:
Prototype insights

7.3 Conclusion

Safety is a primary concern in the concept design, particularly to prevent tipping over. Embedding the cabinet into the ground, a familiar method for local community members, ensures stability. For middle-income households with solid walls, mounting to the wall can be explored, while now the possibility of mounting for extra security was shown. The cabinet significantly enhances household hygiene by reducing dust accumulation and keeping items off the ground and away from mud walls. Its smooth, washable plastic finish facilitates easy cleaning, while elevated shelves prevent insects and animals from reaching stored items. Designed for DIY assembly, the cabinet includes an easy-to-understand manual, requiring minimal tools. This approach supports local SMEs in assembling and selling the products, creating jobs and keeping production costs low. Overall, the concept fits in the design focus and the created framework while further developing towards a product that fits in the local culture and is safe to use.



Figure 65: Photo of the first prototype



To determine the effectiveness and alignment of the concept with the established design focus, final tests were conducted involving end users and EcoWorld employees. These tests were facilitated remotely through videos, photos, and a questionnaire sent to participants. This chapter presents the insights from the test, based on the researched sub questions, to evaluate if the concept effectively addresses the research goal and the stakeholder map from section 1.4.1. Next the impact of the design is shown and the chapter ends with a conclusion.



Figure 66: The very first prototype back in Watamu

Chapter Overview

- 8.1 Validation Approach
- 8.2 Evaluation of the Prototype
- 8.3 Evaluation of the Concept
 - 8.3.1 End User Feedback
 - 8.3.2 Employee Feedback
- 8.4 Impact of the Concept
- 8.5 Conclusion

8.1 Validation Approach

The primary research goal was to assess whether the plastic waste cabinet concept was functional, recognizable, and feasible to produce locally within the context.

Based on the design requirements (see section 5.3), the following sub questions were created:

Prototype

Functionality: Does the concept function effectively for daily use?

Employees

Comprehensible and Feasible: Do employees understand the production process?

End Users

Functional and Recognizable: Does the design fit within their homestead?

Involvement and Education: Does the design encourage users to close the waste loop?

The end-user questionnaire focused on testing the concept's desirability and viability, with questions about usability, shape and willingness to buy. Instructions for assembly and the digging-in approach for safety were given to the end users. This aimed to ask for their opinion on self-assembly, the digging-in process, and the comprehensibility of the prototype's use cases. Feedback was also sought on the buy-back scheme to ensure understanding of the intended disposal method for plastic products at their end-of-life. The questionnaires can be found in appendix I.

The test included 10 EcoWorld employees and 10 local end users. Additionally, a cultural translator, who was present at the creative sessions, conducted the on-site interviews. Integrating a cultural translator ensured that the questionnaires were clearly understood and aligned with the desired outcomes. The questionnaire for manufacturers aimed to assess feasibility in the local context, allowing for feedback on the design and production process. It included the concept template, various descriptions of the new machines and tools, and instructions for cutting, using, and producing the final concept. The assembly process was demonstrated to ensure comprehension, and their overall opinion was asked to give room for their involvement and to use their expertise on producing in the local context.

8.2 Evaluation of the Prototype

As outlined in the previous chapter, ensuring the structural integrity of the concept, so that it functions during daily use, requires testing with a plastic shelf. Initially, the shelf was modeled using the properties of recycled PP to evaluate its behavior under load. It was found that the shelf would bend a maximum of 2.8mm under a 20 kg load, which is negligible and ensures structural stability (see appendix J). However, modeling the tension of the lashing strap proved challenging, necessitating a prototype.

Recycled PS plastic sheets were sourced from the BioPlastic company to create a 12 mm shelf for the prototype. The shelf was cut to fit in the prototype and subjected to tension from the lashing strap. Testing revealed that the shelf bent by a maximum of 2mm when placed as the highest or lowest shelf, with no further bending under a load of 10.5 kg (see figure 67). The Tensile Modulus, indicating stiffness and deformation under pressure, is higher for recycled PP (1704 MPa) than recycled PS (1500 MPa) (Rosli, 2021). This confirms that the prototype will hold its shape when made of recycled PP, as the deformation will be less than with recycled PS.

Experts in the field validated these findings, concluding that the deformation was insignificant and that the overall function and strength of the concept remain intact. The concept was also reviewed by the Better Future Factory in Rotterdam for additional expert opinion. This company specializes in designing products made from recycled plastic and has extensive expertise with this material. They were very enthusiastic about using the lashing strap and the material choice of PP. They prefer PP because it is one of the few plastics that emits very few toxic fumes when melted.

Additionally, when PP breaks, it does not leave sharp edges like other plastics, and it is easy to clean. In their opinion, the lashing strap provided sufficient strength to the structure, and the small deformation observed was negligible. Their recommendations include being mindful of tolerances and considering the effects of high-temperature climates, which can cause the material to shrink and expand.

The weight of the recycled PS shelf is 1.81 kg. When recalculated for recycled PP with a general density of 0.9 g/cm^3 , the weight per shelf is approximately 1.53 kg. The scale of the prototype is 2:3, which results in a total weight of the cabinet of 11,5 kg. The material was easy to handle, and the finishing process was straightforward with minimal slots and holes that can be easily drilled. With an efficient assembly and production line, and the development of manufacturing skills, producing the final concept should be feasible in the local context.

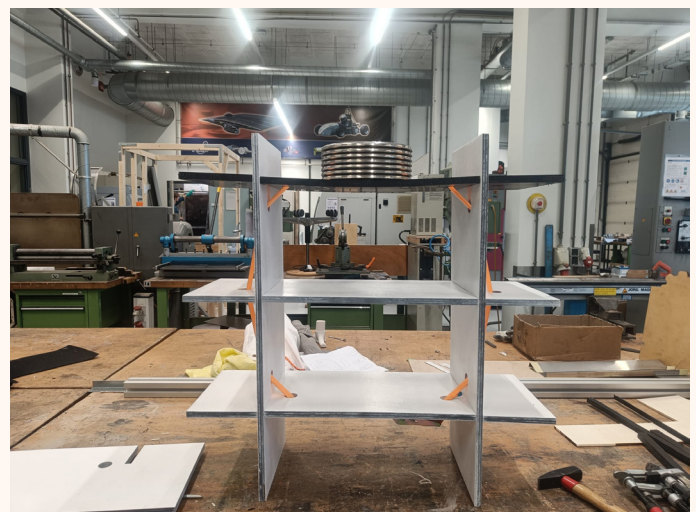


Figure 67: The plastic shelf put under load and stress

8.3 Evaluation of the Concept

8.3.1 End User Feedback

End users were interviewed to assess the fit of the concept within the local context, focusing on the shape, willingness to buy, and functionality. The design shape was found to be recognizable and aligned with their need for cabinets in their households. The assembly manual and the digging-in approach were comprehensible, and participants indicated they would use the digging-in method for safety. Although they preferred a pre-assembled cabinet, they understood the assembly process and the use of the lashing strap. The end users also showed a willingness to buy at the established prices which all together demonstrates the concept's suitability for local households. The primary feedback was on the size, which will be addressed in the recommendation section.

To test user engagement in closing the loop, the buy-back scheme visual was presented. Users understood the concept of returning broken elements and appreciated its role in lowering costs and promoting circular goals. They recognized the importance of spreading awareness and felt encouraged to discuss the product and actively promote circular behavior to others. Users viewed the concept as a valuable first step in creating new value from plastic waste, feeling inspired by its potential benefits. However, they also acknowledged it is not the ultimate solution and expressed interest in innovations that are decomposable or reduce plastic consumption upfront. While they were open to using this material for other products over time, some hesitation remained due to its novelty. They showed a willingness to purchase it as a cabinet, but found the idea of using it for chairs or benches to be less convincing at this stage.

8.3.2 Employee Feedback

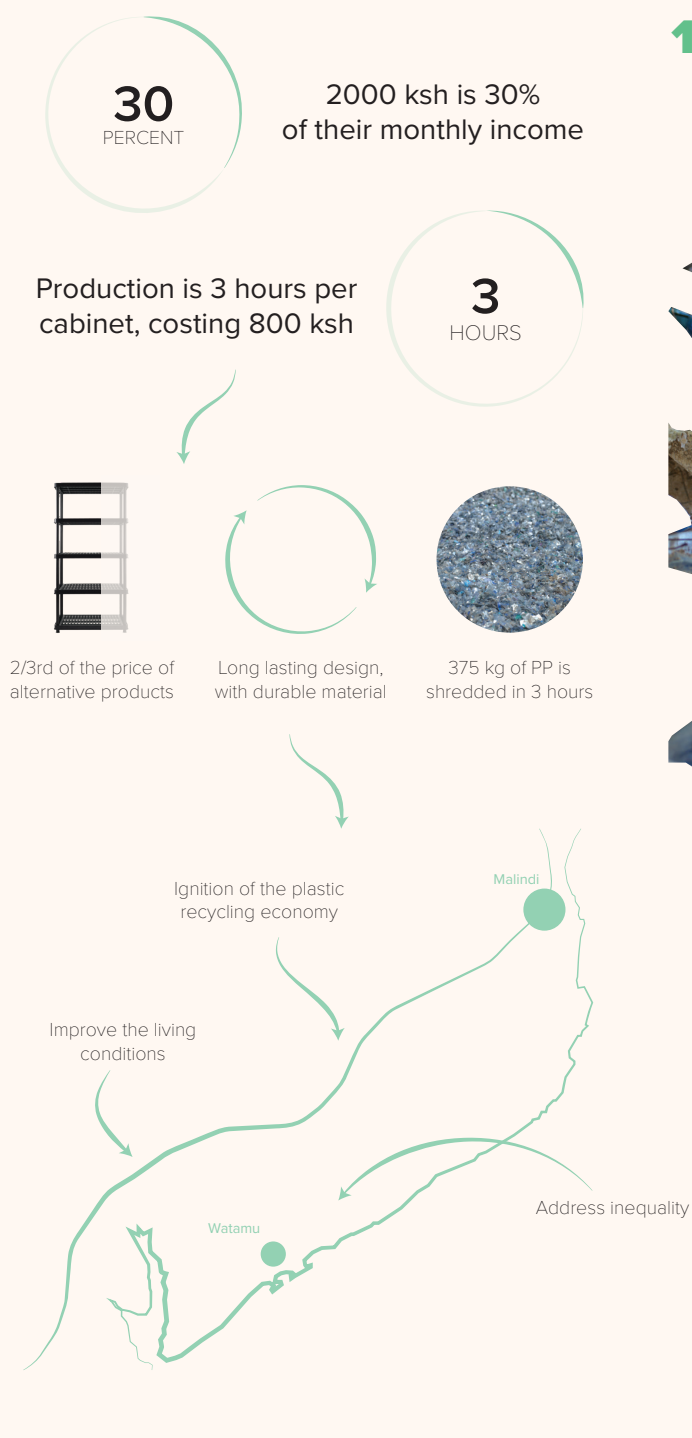
EcoWorld employees were interviewed to gather their opinions on the assembly and production process, as well as the skills required to produce the concept. The interviews revealed that the provided template and production process were well understood by the employees. They indicated familiarity with the machines used for finishing the plastic sheets, although none had prior experience with a sheet press. However, they expressed a strong willingness to learn and develop their skills in producing products from plastic waste material.

In terms of feasibility, employees noted that while they currently lack the tools and expertise to produce these products at scale, they are eager to explore ways to maintain consistent product quality. They appreciated the simplicity of the product and were optimistic about its implementation at EcoWorld and in the local market. Their primary concern was the strength of the material, an issue addressed in the previous section with the prototype. Some time will be needed to refine the production process in the local context to ensure a quality shelf.

To conclude, The concept effectively provides storage solutions for local households in Watamu, demonstrating a strong willingness to buy among end users and feasibility for production by EcoWorld employees, creating benefit for all stakeholders addressing the stakeholder map described earlier (section 1.4.1). The design process involved local end users and encourages them to participate in closing the waste loop, raising awareness and knowledge about handling plastic waste.

8.4 Impact of the Concept

This concept impacts the emerging local recycling economy by increasing knowledge and awareness among end users. It represents the first step towards igniting this economy and integrating women and youth into the local employment market. The concept builds trust in the new material, paving the way for future structural elements in housing. It also creates new job opportunities by enabling SMEs to assemble and retail the product, expanding the economy and involving more local communities in the process.



1000 Disposable Packages



Figure 68: Impact overview

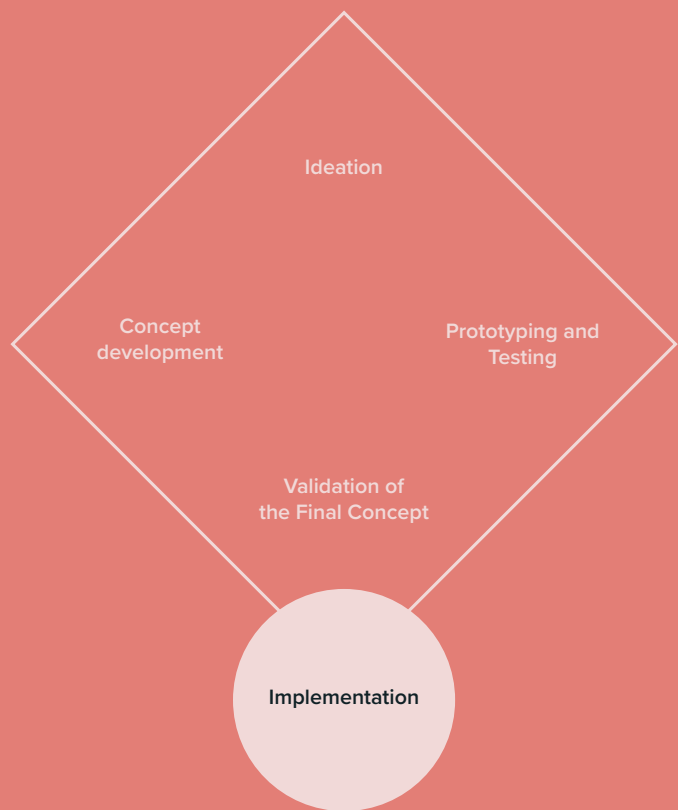
8.5 Conclusion

The final tests confirmed the effectiveness and feasibility of the plastic waste cabinet concept within the local context of Watamu, Kenya. The design was found to be functional, recognizable, and producible using locally available resources. EcoWorld employees understood the production process and expressed a strong willingness to learn and adapt to new techniques, despite some initial unfamiliarity with specific machinery. End users responded positively to the design, appreciating its practicality and expressing a willingness to purchase the product, although they preferred pre-assembled units.

The project successfully integrated the perspectives and needs of local end users, which is crucial for closing the waste loop and enhancing the circular economy. By involving end users in the design process, the concept not only provides practical storage solutions but also raises awareness and encourages active participation in sustainable practices. This approach aligns with EcoWorld's goal of shifting from mere recycling to upcycling, creating more social value from locally collected plastic waste. The positive feedback from both employees and end users underscores the potential for this concept to improve living conditions and stimulate the local economy in Watamu.



Figure 69: Final prototype with the plastic shelf



09

Implementation in the Local Context

This research originated from EcoWorld's request to transition from mere recycling to circular design, aiming to improve the living conditions for the local community in Watamu. Initially, EcoWorld envisioned designing plastic bricks to construct better and more affordable housing. However, it was discovered that the local people are not yet ready to shift from their traditional living methods to plastic housing. Through this research, a framework was established to visualize circular design in this context, culminating in a final concept designed as a first step towards enhancing living conditions in Watamu. This chapter will first introduce a way to implement this concept in the current local market, as well as ideas on future products that fit in the local market. Next a transition model, visualizing the path from implementing this initial concept to an envisioned future of building houses from plastic waste bricks is introduced in a strategic roadmap.



Figure 70: Tour at EcoWorld for tourists and locals

Chapter Overview

9.1 How to implement this concept in the local market

9.1.1 Implementation at EcoWorld

9.1.2 Implementation with End Users

9.1.3 Future Product Inspiration

9.2 Transition Model

9.2.1 Increase Trust

9.2.2 Increase Involvement

9.3 Recommendations

9.4 Conclusion

9.1 How to implement this concept in the local market

9.1.1 Implementation at EcoWorld

To implement this final concept in the local market, EcoWorld needs to adopt new manufacturing technologies. Currently, EcoWorld relies on injection molding machines for production, while their sorting and shredding processes are well established. To realize this concept, a sheet press needs to be introduced. Several companies and institutions along the Kenyan coastline, such as the International School of Kenya, already use this machine. A practical starting point would be to use the blueprints from Precious Plastic to build the machines locally in Watamu. These blueprints provide details on cost, dimensions, and other requirements for implementing the technology. Collaborating with other institutions will further support the introduction of this new machine.

However, there are two main challenges with introducing the sheet press: cost and the required skill to operate the machine. EcoWorld is currently able to purchase new machines with the help of grants and is actively seeking to integrate a sheet press and extruder at their factory, they estimate to have the machines running after the summer of 2024. Field research indicated that some manufacturers at EcoWorld are already familiar with sheet press operations from previous jobs, and other employees have shown interest in learning new technologies. This indicates a strong potential for successfully adopting this manufacturing technology at EcoWorld.

The next step involves scaling up production once the process is refined. Establishing an efficient production line, including sorting, shredding, washing, pressing, finishing, and packaging phases, is crucial. Properly arranging the machines in the factory to follow this sequence will enhance efficiency. Figure 71 illustrates the proposed production line and provides information about each phase. The proposed sheetpress is from the precious plastic company. The finishing tools that are needed are a drill and a router to cut and finish the sheets.

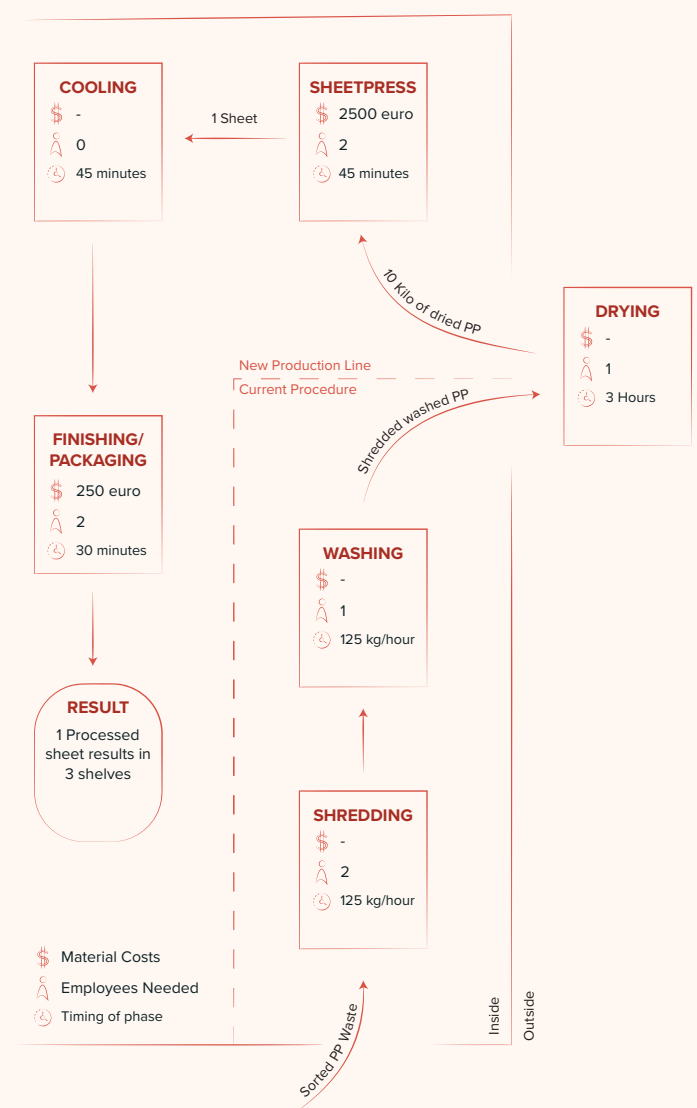


Figure 71: Production line

In addition to manufacturing challenges, the influence of the quality of the raw materials and government policies must be addressed. Interviews with recycling factories in the Netherlands highlighted the importance of raw material quality when designing with recycled plastic. This involves quality control of incoming plastics and a cleaning station after shredding to ensure high-quality output. Currently, EcoWorld has a significant supply of PP waste, while there is no market for this material in Kenya. Growing towards a consistent supply of PP is essential, but the emergence of a false market, discussed in section 1.4.2, complicates this. EcoWorld believes that such markets cannot sustain in the near future, but caution is necessary as it can affect the supply of raw material.

Kenyan government institutions encourage the development of products made from recycled plastics, and EcoWorld has strong ties with these institutions, receiving substantial support, particularly in funding. These relationships will aid in the implementation of new products in the local market with government backing.

9.1.2 Implementation with End Users

Tailoring the concept design to end-users enhances its adaption in the local market, as discussed throughout this research. The design is familiar and recognizable to users as they already own cabinets and other storage solutions. The target group, with a low income, focuses on replacing these broken appliances rather than acquiring other new products. Therefore the concept was designed to align with their lifestyle and household needs. However, integrating the new material into the local market presents a challenge due to its novelty. The hands-on approach of the product forces users to interact with the material and discover the potential and versatility of the material. To further promote this material, hosting talks and workshops with local communities will increase knowledge and awareness of plastic waste as a resource. Establishing SMEs to promote and sell these products will also enhance skill and knowledge development. The retail price of the products has been adjusted to the wallet of the end users, creating a durable yet affordable product in the local market. This, together with the buy back scheme will incentivize the user to buy and return the broken components and products, moving towards circular behavior. This implementation is visualized in a timeline shown in figure 72.

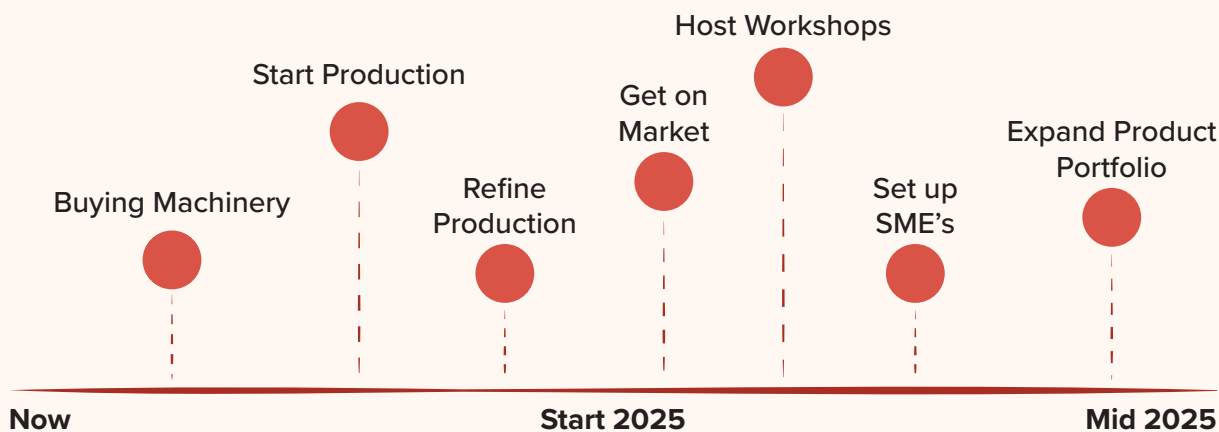


Figure 72: Implementation timeline

9.1.3 Future Product Inspiration

Expanding the product portfolio beyond the proposed cabinet reveals numerous possibilities. Creative sessions highlighted that end users are open to furniture items made from plastic and tiles for floors or walls in the future. Furniture can cater to low to middle-income individuals in Watamu, while tiles currently appeal more to the higher-income segment. However, this may change as trust in the material grows and costs become more accessible for lower-income households. Globally, companies are increasingly developing products from plastic waste, marking a growing trend. This trend opens up numerous opportunities for EcoWorld to form partnerships and draw inspiration for new products. Figure 73 illustrates some emerging products made from plastic waste.

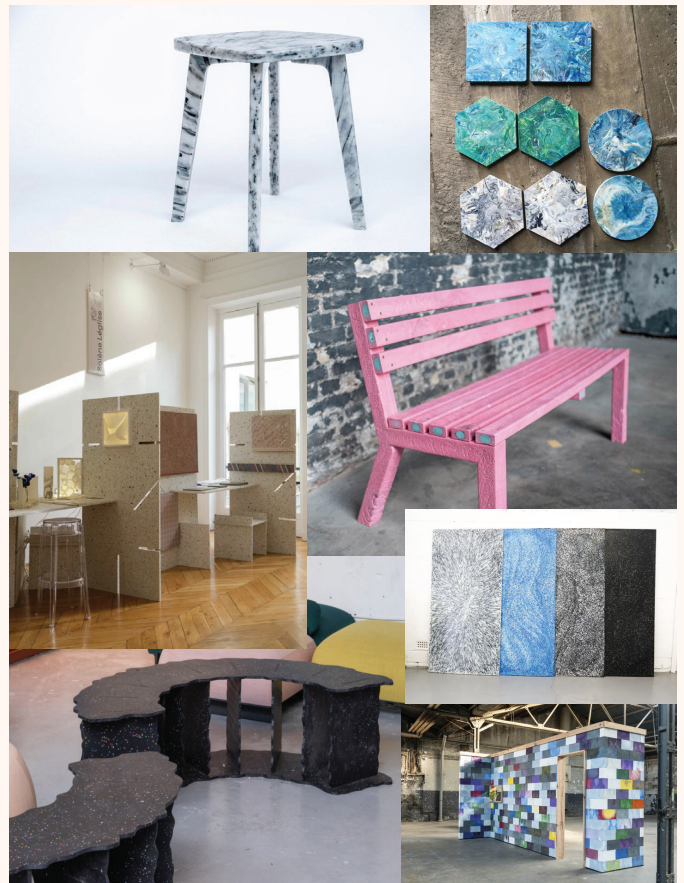


Figure 73: Alternative products in the future

9.2 Transition Model

Throughout the research, it became clear that the involvement of the end user is crucial for the successful implementation of this new material within the emerging economy. The transition model, see figure 74, visualizes the connections between EcoWorld’s ecosystem, their product portfolio, and the end users, highlighting their involvement. This transition is divided into three phases: short-term, mid-term, and long-term implementation, each with its own value proposition and portfolio development. The key links between these phases are the increase in trust in the material and the growing involvement of the end user.

9.2.1 Increase in Trust

Trust in the material among end-users grows over time as they gain access to products made from plastic waste. Initially, these products may include storage solutions, wall and floor tiles, and gradually expand to furniture in the short term. As trust in the material increases, knowledge about these products will spread among the communities and EcoWorld’s employees. This knowledge development will enhance employees’ skills and expand the product portfolio as they understand the material’s potential more deeply. Eventually, this established trust will lead to the acceptance of plastic as a building material in the long term. By consistently engaging and informing the end-user, EcoWorld can raise awareness, enhance knowledge, and increase acceptance of these products, thereby evolving their product portfolio to meet the needs of the local market.



Figure 74: Transition Model

9.2.2 Increase in Involvement

Alongside building trust, EcoWorld's mission is to ignite the emerging economy, particularly for women and youth. The transition model illustrates this involvement by incorporating SMEs after establishing skills and knowledge within the local communities. Once the basic understanding of the material's potential is in place, SMEs can create businesses around these products.

As the market adopts these products, SMEs can take over retail operations from EcoWorld, creating job opportunities and stimulating the economy. Furthermore, production can be expanded along the coastline, allowing EcoWorld to shift its focus to managing the eco-waste cycle. This approach, described in section 3.3, involves a company managing the entire network along the value hill. The transition model thus presents an opportunity for EcoWorld to transition to waste management, enabling local communities to handle production and retail, leveraging the established trust and involvement over time.

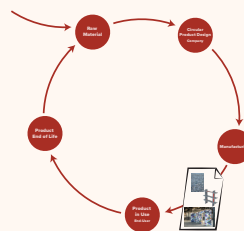
MID TERM

Empower women and youth to drive the local circular economy by supporting small enterprises that sell EcoWorld products, while addressing inadequate housing conditions with sustainable construction materials building upon this established trust.



LONG TERM

Optimize coastal waste management on the Kenyan Coastline by managing the entire eco-waste stream, empowering the local community to lead production, collection, and distribution.



ADAPT TO FIT THE LOCAL CONTEXT

MANAGE THE ECO-WASTE STREAM

EMPOWER WOMAN AND YOUTH BY IGNITING THIS EMERGING ECONOMY

PRODUCE LOCALLY

CREATE PRODUCTION LINES ALONG THE COAST

EMPLOY

SPREAD KNOWLEDGE ON CE AMONGST END USERS

SET UP LOCAL SME'S

DEVELOP THE SKILLS OF LOCALS

ESTABLISH INTERNATIONAL PARTNERSHIPS

EXPAND ALONG THE KENYAN COASTLINE

EXPAND COLLECTION AND CLEAN UPS

SKILL AND KNOWLEDGE DEVELOPMENT

BUILDING A COMMUNITY NETWORK

WORK AT THE NEW SME'S

TAKE OVER LOCAL PRODUCTION

9.3 Recommendations

Size of the Concept

End users suggested that the cabinet could be larger to store more items. To accommodate this, additional slots could be added to create a more modular system, allowing users to combine different cabinets for expanded storage space. This would make the cabinet suitable for various parts of the home, not just the kitchen, making it multi-purpose.

Circular Lashing Strap

To simplify the product and reduce costs, it is recommended to use a normal clamp instead of a ratchet for the lashing strap. This clamp can hold the same amount of force and is easier to install. These straps, which can be produced in-house at EcoWorld from recycled bags, used to store and ship flakes, offer a cost-effective and sustainable solution.

Machinery

To further develop their business, EcoWorld should consider sourcing new machinery. While the introduction of a sheet press has been discussed, continuous innovation and research into new machinery are essential for optimal implementation and growth of the business. This includes exploring the use of an extruder and other machinery to enhance the skills and knowledge of employees.

Quality Control

Establishing a robust quality control protocol is crucial when working with waste materials. EcoWorld should conduct research to ensure that the collected waste materials meet the desired quality standards. This includes setting protocols for both the raw materials and the final products to ensure they are durable and competitive in the market.

Community Network

Building a community network to discuss plastic pollution and how the community can contribute to environmental clean-up is recommended. This will increase community involvement, enhance understanding of EcoWorld's activities, and promote the versatility of plastic waste materials. Maintaining an open-source approach and sharing knowledge with other local developers in Kenya and Africa will help collectively address the plastic pollution problem.

Research on Material Wear

Further research on the wear and durability of the products in local conditions is recommended. This includes studying the behavior of the materials in Watamu's climate and the spread of microplastics. Subjecting the concept to local conditions will help ensure its durability and assess the impact of degradation on its structural integrity.

9.4 Conclusion

This research by EcoWorld aimed to transition from recycling to circular design in Watamu, Kenya, initially focusing on plastic bricks for housing. However, the first focus should be on familiar and simple products to start the local development of this emerging economy. To implement this first concept, EcoWorld plans to integrate a new machinery, educating local employees and building their skill set.

Engaging end users is imperative, with the concept designed to encourage circular behaviors through workshops and community engagement. The transition model outlines a roadmap for EcoWorld's growth, starting with building trust in plastic products like storage solutions and expanding the product portfolio over time. This trust-building process aims to eventually establish plastic as a trusted building material.

Next to that, EcoWorld seeks to increase community involvement, particularly among women and youth, by fostering SMEs that can handle retail operations, allowing EcoWorld to focus on waste management.

Several recommendations emerged from this research. The product should be improved by enhancing the cabinet's size and modularity and simplifying the lashing strap. Continuous innovation and research into new machinery are essential for optimal implementation and growth. Quality control protocols must be established to ensure the durability and competitiveness of products. Building a community network to discuss plastic pollution and promote recycled materials is also recommended. Additionally, further research on the wear and durability of products in local conditions is necessary to ensure their longevity.

In conclusion, this research successfully established a foundation for EcoWorld to transition to a circular design approach. By focusing on practical, recognizable solutions and involving the community, EcoWorld can enhance local living conditions and stimulate the economy. The strategies and recommendations provided will help EcoWorld achieve these goals, fostering a sustainable and circular economy in Watamu.

10

Conclusion and Discussion



Figure 75: Artwork made from plastic waste on the beach

Chapter Overview

10.1 Conclusion

10.2 Discussion

10.1 Conclusion

The first challenge set at the beginning of this report was to help EcoWorld expand its product portfolio beyond mere recycling to producing upcycled products, thereby improving the inadequate living conditions in Watamu, Kenya. This led to defining upcycling in the local context from an academic perspective; upcycled products should be made from locally collected plastic waste and create more social value for end users, moving beyond mere recycling to other R-strategies that enhance the product's circularity by slowing down the resource loop.

Using the value hill method, EcoWorld was positioned to adopt a circular approach, demonstrating how this can be integrated into a successful local business model. Additionally, a circular product life cycle framework was developed to guide the design process using a circular approach. Both the value hill and the framework highlighted that end users were not yet integrated into the product life cycle, despite their crucial role in adding value and closing the waste loop at the product's end of life.

This leads us to the next challenge, addressing inadequate housing and closing the knowledge gap by integrating the end users into the design process. Initial context and stakeholder analyses revealed significant inequality and poor living standards in Watamu, exacerbated by a harsh climate and inadequate housing. EcoWorld seeks to tackle these issues by creating dynamic waste value streams, igniting the emerging local recycling economy, and addressing inequality by involving women and youth as key drivers.

The end user analysis highlighted that the people of Watamu are practical and hands-on, showing great interest in the emerging recycling economy as a way to earn money and develop their skills.

To fully emerge in the context, a four-week field research trip to Watamu was conducted, integrating end users into the design process through creative sessions, interviews, and observations. It was discovered that while users did not yet trust plastic waste material for construction products like bricks, they saw benefits for smaller furniture or utility items. Hygiene in local homes emerged as a significant issue, with inadequate living conditions making it difficult to maintain cleanliness. These insights shaped the design phase, focusing on creating storage solutions for low- to middle-income households.

Back in the Netherlands, the design phase continued, developing the concept's meaning and form. A concept was created that fits the local context due to its simplicity, recognizability, and hands-on approach, making it feasible for production at EcoWorld with the involvement of local employees. This concept fits to the circular design approach by improving living conditions, being affordable and durable for end users, and incorporating a buy-back scheme to close the loop and include end users in the product life cycle. Altogether this concept improves the current living conditions, and enhances the public awareness about the impact of plastic on the environment.

This concept represents the first step in building trust and involvement among end users, helping them acclimate to this new material. It also marks the initial move toward igniting a new emerging economy. A transition model visualizes how established trust and involvement can lead to the creation of local SMEs, further stimulating the economy and allowing EcoWorld to focus on waste management along the Kenyan coastline. This transition model shows a possible effective waste management strategy, addressing the last challenge set at the beginning of the report. Ultimately, this concept achieves the goals of igniting the local economy, addressing inequality by creating new jobs, and transitioning from mere recycling to a circular design approach that involves and incentivizes end users to clean the environment.



Figure 76: Artwork made from plastic waste at EcoWorld

10.2 Discussion

Influence of an European Design Student

The first point that needs to be addressed is the influence of a design student from Europe conducting a project in an unfamiliar culture. Throughout the entire research, the approach was to adopt a bottom-up strategy, learning from the local expertise of the client and the end users. Through interviews, language learning, and the integration of a cultural translator, the designer tried to align the approach with the local culture and context. However, it must be acknowledged that a 'western perspective' inevitably influenced this research.

Culture and Language Barriers

Another critical issue is the culture and language barrier affecting communication. Despite the designer's efforts to learn and remain open to the local culture, the need for the cultural translator to convey all insights during interviews and creative sessions posed challenges. Even with thorough preparation to align nuances, it is likely that some insights were lost due to this barrier, and some questions may have been misinterpreted. Communicating meaning and nuances remotely during the validation stage proved particularly difficult.

Prototype Validation Challenges

Additionally, it was unfortunate that the prototype could not be built locally in time for the tests. As a result, validation tests had to be conducted using videos and photos of the scaled prototype made in the Netherlands. This hindered the accurate perception and demonstration of the concept's actual size to the end users. Despite the designer's efforts to use other visuals to represent the actual size, effectively communicating this to the cultural translator was challenging. This miscommunication about the prototype's scale diverted feedback focus away from other design elements.

Implementing New Technologies in a Developing Country

Lastly, implementing new technologies in a developing country always presents complications. The primary struggle is financial; although EcoWorld currently has grants, expansion and innovation heavily rely on securing such funds, which is challenging. Additionally, the harsh climate of Watamu complicates the integration of new technologies. Heavy rainfall, extreme heat, and frequent power outages create difficult working conditions and safety concerns at local facilities. Power outages, in particular, pose significant challenges for operations dependent on consistent electricity, such as using a sheet press or extruder, where a sudden outage can compromise the quality of the end product.



Figure 77: Final Prototype in use

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Appendices

Overview

- A. Initial Design Brief
- B. Preperation Design Sprints
- C. Concept Direction Pages
- D. Explenation Harris Profile 1
- E. 3 Concept Pages
- F. Explenation Harris Profile 2
- G. Questionnaire 1
- H. Assembly Manual
- I. Questionnaire 2
- J. Modelling Shelf

A. Initial Design Brief



Personal Project Brief – IDE Master Graduation Project

Name student Leander Hombergen

Student number 4535111

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Project title

Expand EcoWorld's product portfolio with meaningful designs for local Kenyan people from collected plastic waste

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

EcoWorld Recycling is a social enterprise, on a mission to restore Kenya's coastline by removing plastics and converting them into construction materials and other products of local and commercial value. However, they face the challenge of limited technology and expertise to explore new possibilities for the plastics they collect. EcoWorld's next objective is to diversify their product portfolio by researching and developing innovative, sustainable applications for collected plastics. These products should be designed to the local community's needs or tap into international markets for revenue generation, ultimately supporting EcoWorld's environmental mission.

Stakeholders:

- EcoWorld, expanding their current product portfolio to gain monetary value or create value for the local municipality.
- Local Kenyan residents, customers of EcoWorld's products. Looking for affordable housing possibilities
- EcoWorld workers, understand new technology and create knowledge about the possibilities with the collected plastics.
- 'The ocean', cleanup the ocean and create awareness amongst local municipalities, in an effort to divert ocean bound waste along the coast.

Opportunities:

Meaningful Co-Creation: Collaborate with the local community to create circular products aligned with their preferences and values.
Research Circular Economy in the Global South: Explore the adoption of circular economy practices in Kenya to align with global sustainability goals.

Limitations:

EcoWorld's current limited technology and their exclusive use of collected plastics may limit their product range and innovation potential.

→ space available for images / figures on next page

Personal Project Brief – IDE Master Graduation Project

Problem Definition

*What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)*

EcoWorld is currently primarily focused on the collection of ocean borne and ocean bound plastics to reduce plastic pollution impacts on the environment. They have yet to explore the potential of these collected plastics for other applications due to low resources to do so. Next to the environmental impact of plastic pollution, the value of the material is not fully used at this stage and EcoWorld only sells it as chips which is of low value in comparison to upcycled products. Currently, the products at EcoWorld are only recycled and they want to move towards upcycled products focussed on the local housing market that hold more value for the company. With this project we tackle this problem and see it as an opportunity to create products that hold meaningful value for the local community, which in turn will result in environmental and socio-economic benefits. EcoWorld can gain deeper insights into local attitudes, expand their product offerings, establish collaborations, and create employment opportunities through innovative small scale technology. This holistic approach not only supports their environmental objectives but also their socio-economic objectives by diversifying plastic value chains, and boosting the plastic circular economy.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Design one or a range of products within housing utility to create understanding about the product possibilities and the impact of upcycled ocean plastics that are designed with and for local kenyan people in Watamu.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

Extensive desk research and interviews with industry experts, innovators, and stakeholders involve collecting data on relevant topics, like the awareness of recycled ocean plastics in the global south. Preparation of the co-creation methods usecases in Kenya. Gain a better understanding of these methods and their impact in the global south. And how to use them in a different culture context. In Kenya I would like to delve into the local context to proceed with understanding the context. By observational studies in households and co creation methods to understand their perspective on upcycled products and to refine the concepts through end-user experiences, aligning them with local needs and desires by developing small prototypes together. The goal in Kenya is to test the assumptions made by the literature studies through real life observations and workshops with the local community. After the Kenya fieldwork, the project returns to the Netherlands for evaluation. Recommendations, shaped by gathered data and experiences, aim to enhance the concept. These insights drive refinements in prototypes and aid in effectively communicating possibilities to the client.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	22 Jan 2024
Mid-term evaluation	25 Mar 2024
Green light meeting	3 Jun 2024
Graduation ceremony	8 Jul 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	☒
For how many project weeks	25
Number of project days per week	4

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.

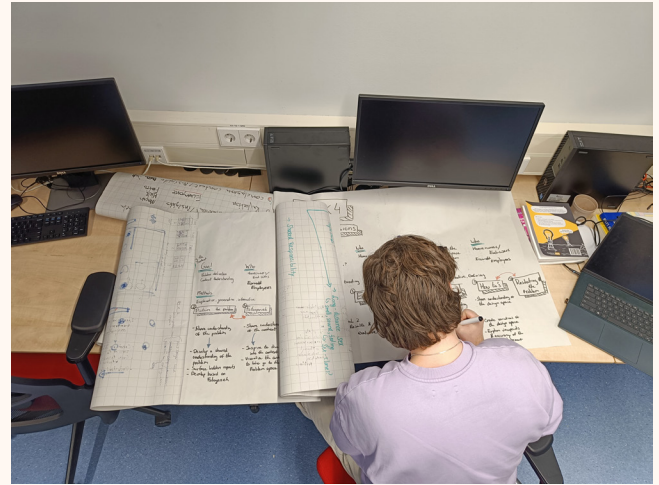
(200 words max)

At the age of 12 I started scuba diving with my father, here my love for the ocean began. This soon led to an interest in the underwater environment, coupled with a somber acknowledgment of its alarming degradation. During my Master's, I aspired to use my background in design as a tool for oceanic restoration. My commitment to sustainable design and inclusivity was explored through a series of relevant elective courses, where my interest only grew larger and I knew that it was something I wanted to explore.

For my graduation project, I aim to use this accumulated knowledge into a challenging project. My intent is to immerse myself in an unfamiliar setting within the global south, learn from the insights gathered to create sustainable design solutions. This project will challenge me with active co-creation sessions with the target community, which I have not done outside of the Netherlands yet. Understanding the culture and motivations of this community is key throughout this project, as it gives me the right tools to design for their unique needs.

Simultaneously, this project offers a platform for personal growth, sharpening my individual project approach, planning, communication, and data synthesis abilities. I want to develop my visual communication skills to effectively convey progress and engage stakeholders. Collaboration with external partners will further enrich my design perspective, and help design towards a solution that we both desire. As a graduate student, I eagerly anticipate this holistic learning experience.

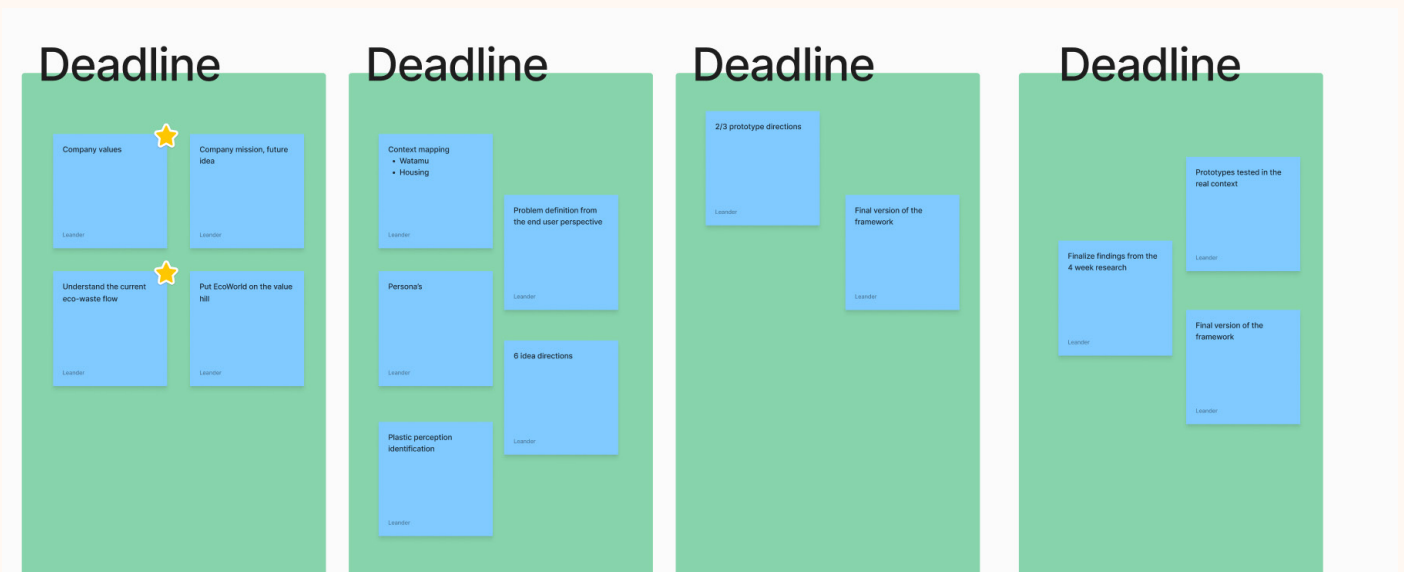
B. Preparations of the Design Sprints



First preparations, outlining all the different co-creation sessions with planning, activities and goals



Pilot testing the sessions together with fellow design students



Deadlines that were set for each week, while it was an iterative approach some deadlines were added along the way.



A 4 week timeline was made to get an insight on the timing of the different activities throughout the design sprints. Below a plan for the observational studies is shown.

Observational Studies



Interview

Who



Start by explaining why they are there and that I am coming to Kenya to conduct research.

- Explain my research and the possibilities and values that it can bring (in short)
- Introduce myself, who I am and what I am doing
- Let them introduce themselves to establish a relationship; name, work, family etc.

Context exploration

- Can you describe what your current house looks like?
- o This is to already get a grip on their perception of their house, what they value and how would they describe a house. What is important to them, what do they highlight, what do they forget?
- Can you talk about routines you have in your house, for eating, washing, sleeping for example?
- o A bit of a day-to-day to see if there are routines in their lives, and which section of the house they use the most. Where do they eat, sleep, wash and what do they use during these activities?
- Are there things in and around your house that are broken and need to be repaired
- o Already drop this question to see what they either do not value and are not bothered to fix or what is super essential for them. If nothing is the answer you can follow up by asking if they fixed something recently and why did it so quickly.
- What is the most important part of your house in your opinion?
- o This can be a nice starting point to look into when diving into the context of location to see if there is some opportunity in this place and why

Material knowledge

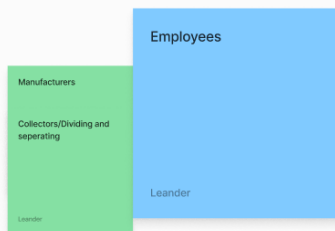
- Do you have a lot of plastic products in your house, and what are they?
- o This is to get a visual on the use of plastic in these housing, is it already common to use a lot of single-use virgin plastic or is it a whole new material? And which kind of products are already made of plastic
- What do you know about the use of recycled plastic?
- o A first look into the perception towards this new material, a first hint towards the actual research in Kenya to get a first impression.

Participation in my research

- o Would you be willing to take part in my research when I am there (explain the research, and what is required from them)
- o After the questions I would like to ask if they would be willing to participate in my research
- o Can you already send me some pictures of the most proud section of your house, what you dislike, and what you would like to see improved in your house?
- o A follow-up question to already have physical tasks for them to get involved in the research, something to grasp.

Further questions:

- What are the most important values of a product for you? What does a product need, for you to buy it?
- What is something that you really want right now? Something that is on your shopping list, but you have not bought yet
- What do you do with broken or out used items, especially made from plastic
- What do you think of all the plastic waste on the street and the beaches?
- What is the cultural value of housing in Kenyan culture? (community hub, status, shelter, not important)



Start by explaining why they are there and that I am coming to Kenya to conduct research.

- Explain my research and the possibilities and values that it can bring (in short)
- Introduce myself, who I am and what I am doing
- Let them introduce themselves to establish a relationship; name, work, family etc.

Context exploration

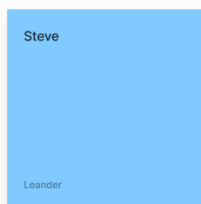
- Can you tell me what you do at EcoWorld?
- o Understand the different jobs at EcoWorld and how the company works.
- Can you describe what the process is from collected plastics to a new product?
- o Understand the current production line and what they do at Ecoworld and identify struggles

Material knowledge

- What do you know about using different kinds of plastics in your job?
- o Trying to understand how they work with this material and how they see it as a potential source
- How open would you be to learning new technologies in processing plastic waste
- o Trying to see if there is a threshold for learning new things

Participation in my research

- Would you be willing to take part in my research when I am there (explain the research, and what is required from them)
- o After the questions I would like to ask if they would be willing to participate in my research



Start by explaining why they are there and that I am coming to Kenya to conduct research.

- Explain my research and the possibilities and values that it can bring (in short)
- Introduce myself, who I am and what I am doing
- Let them introduce themselves to establish a relationship; name, work, family etc.

Context exploration

Ecoworld

- Can you tell me about the origin of EcoWorld and how this company started?
- Background information about the company to understand the idea behind it
- Can you describe the mission of EcoWorld, what do you want to achieve in the end?
- Understand what EcoWorld's core business is about
- What are the main challenges that you are facing at EcoWorld? (internal and external)
- Challenges from their perspective, somethings that I can implement in my research
- What are the core values of the company, what do you stand for and what do you want to portray to the outside?
- Overall picture of what EcoWorld stands for within the local community

Vision of EcoWorld

- How do you see the future of EcoWorld in terms of product portfolio and Circular economy?
- Where do they see the market shift towards and where do they want to grow towards, but also understand their perspective on CE, and their understanding for the possibilities

Plastic pollution in Watamu

- Can you tell me something about the current waste management systems in Watamu?
- What kind of plastics do you gather, and what is being done with each type
- Processing costs numbers, capacity and volumes, what is wanted and what is less wanted
- Do you need to clean the incoming plastic waste?

Framework

- When you look at the framework I made, which areas are the most important for EcoWorld, and where do you see less need/interest?
- Understand their need and solution space for this project, and align that with my view on the matter to design with. Which requirements are important for the company?



Start by explaining why they are there and that I am coming to Kenya to conduct research.

- Explain my research and the possibilities and values that it can bring (in short)
- Introduce myself, who I am and what I am doing
- Let them introduce themselves to establish a relationship; name, work, family, etc.

Context exploration

- Can you describe the process of building houses currently
- o An introduction into the materials, process, and maybe some pain points when asking follow-up questions. But this is also to ease the interviewee into the interview and gathering a holistic picture about the current process
 - Create a picture of the building process and the costs
 - What kind of materials are being used?

Material knowledge

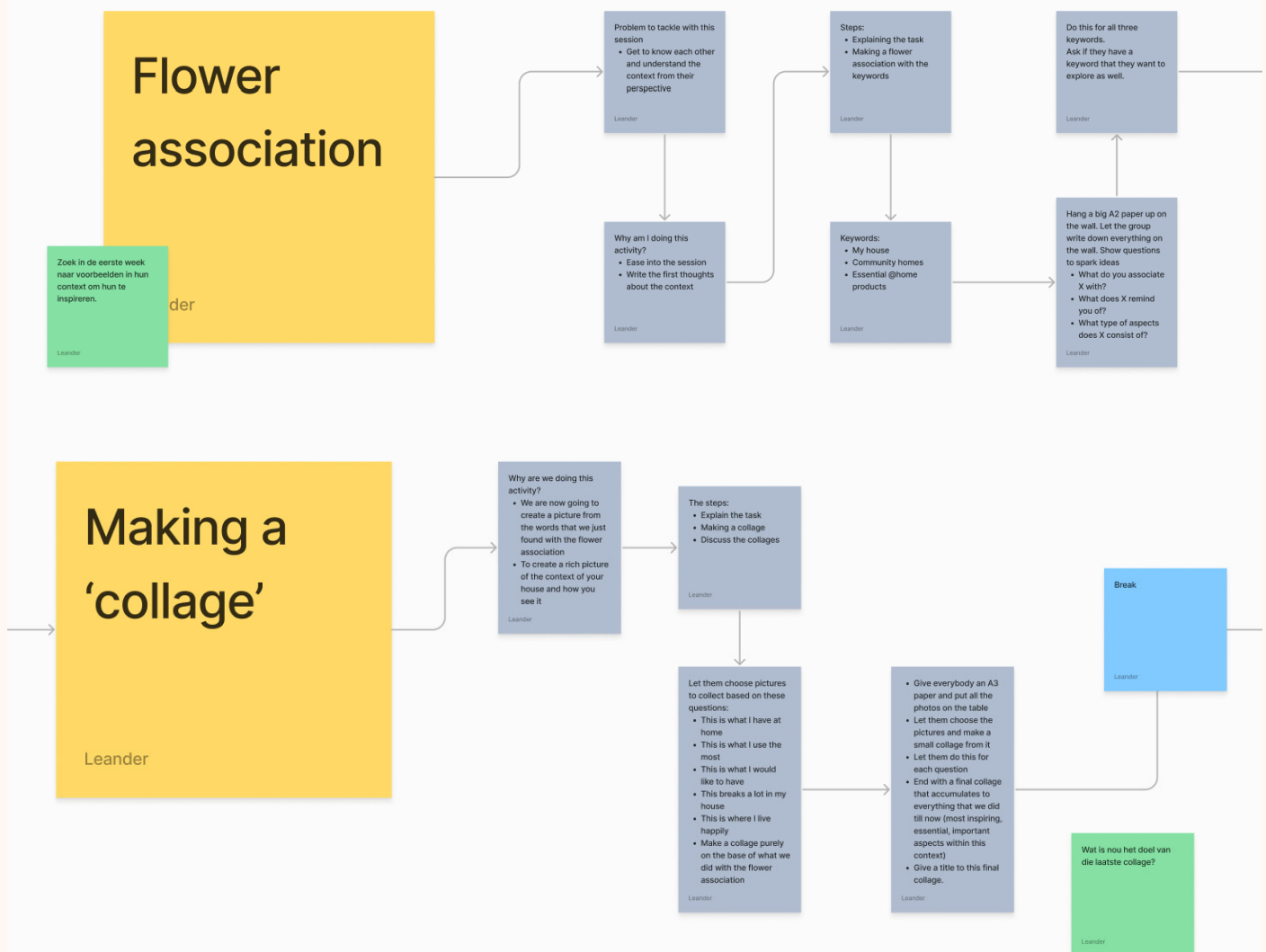
- What do you know about using recycled plastic in your job?
- o Trying to understand how they work with this material and if they see it as a potential source

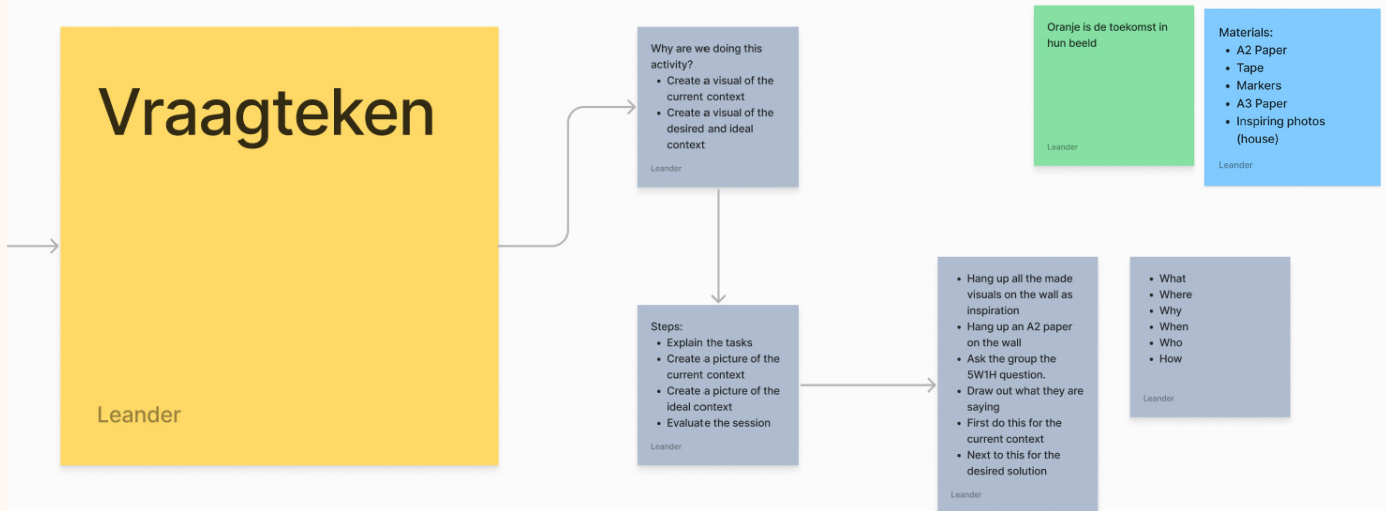
Participation in my research

- Would you be willing to take part in my research when I am there (explain the research, and what is required from them)
- After the questions I would like to ask if they would be willing to participate in my research

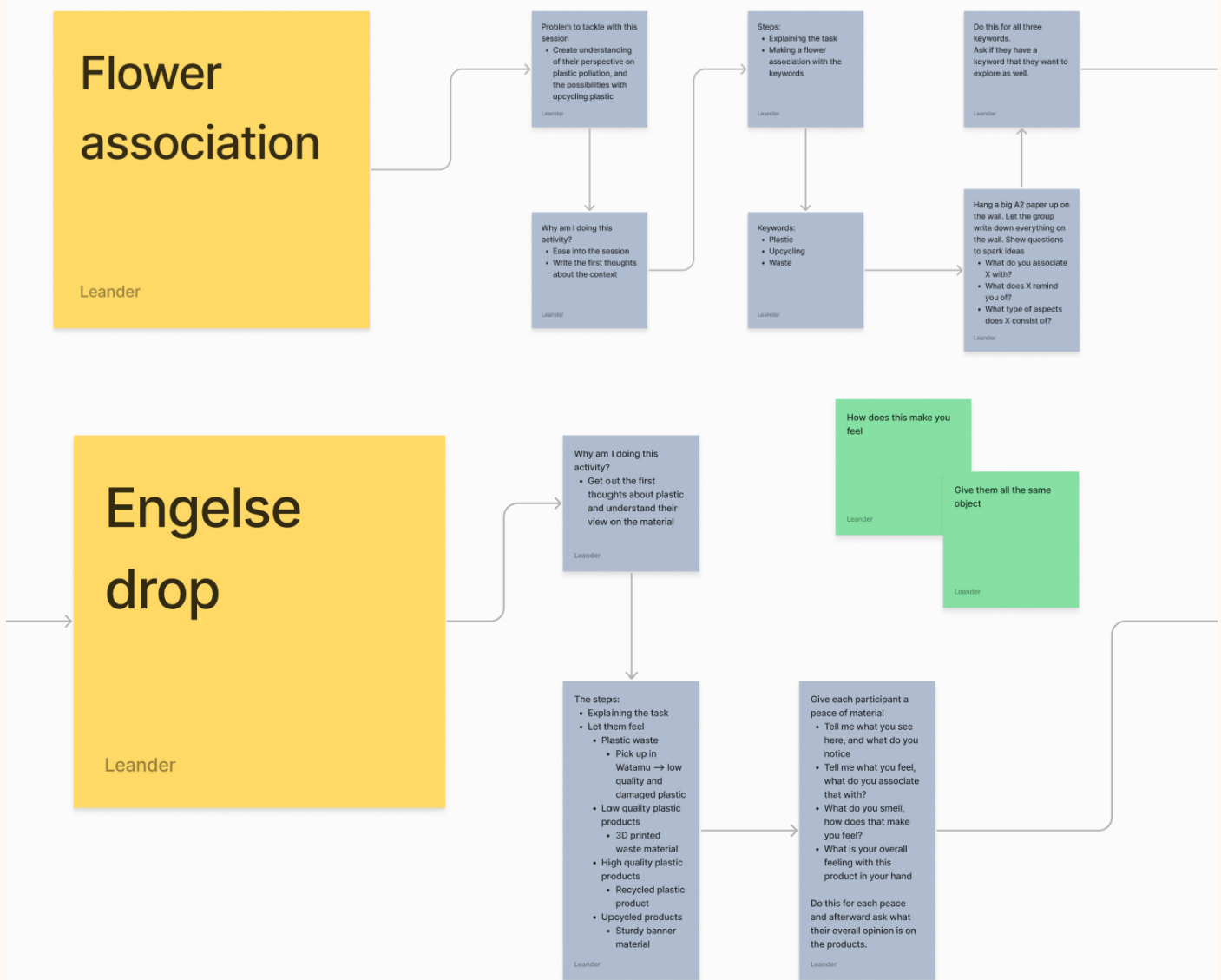
Here the interview questions are shown that were asked during the four week field research. Below the 3 creative sessions are shown with the why, what and how explained for each activity.

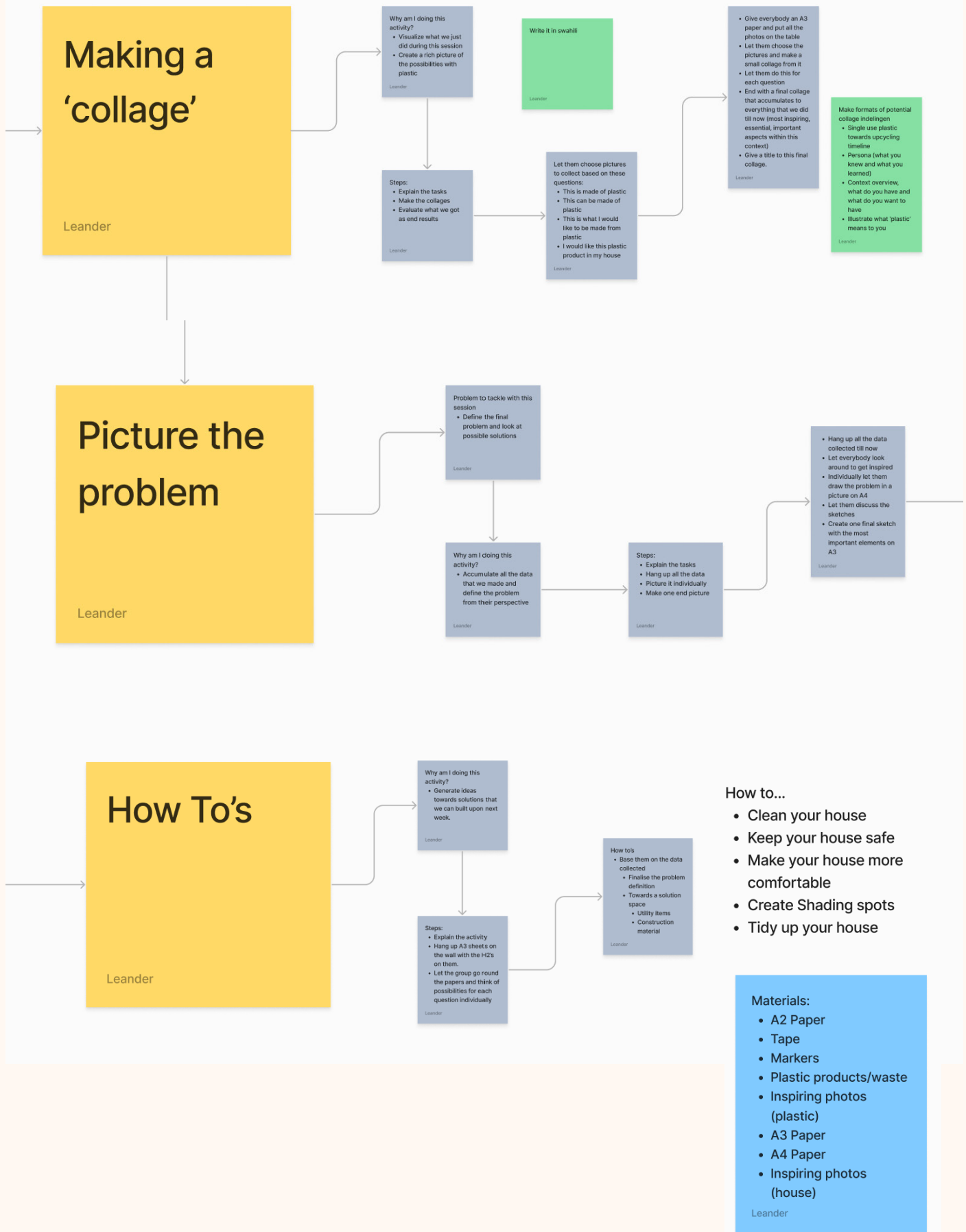
Creative session 1



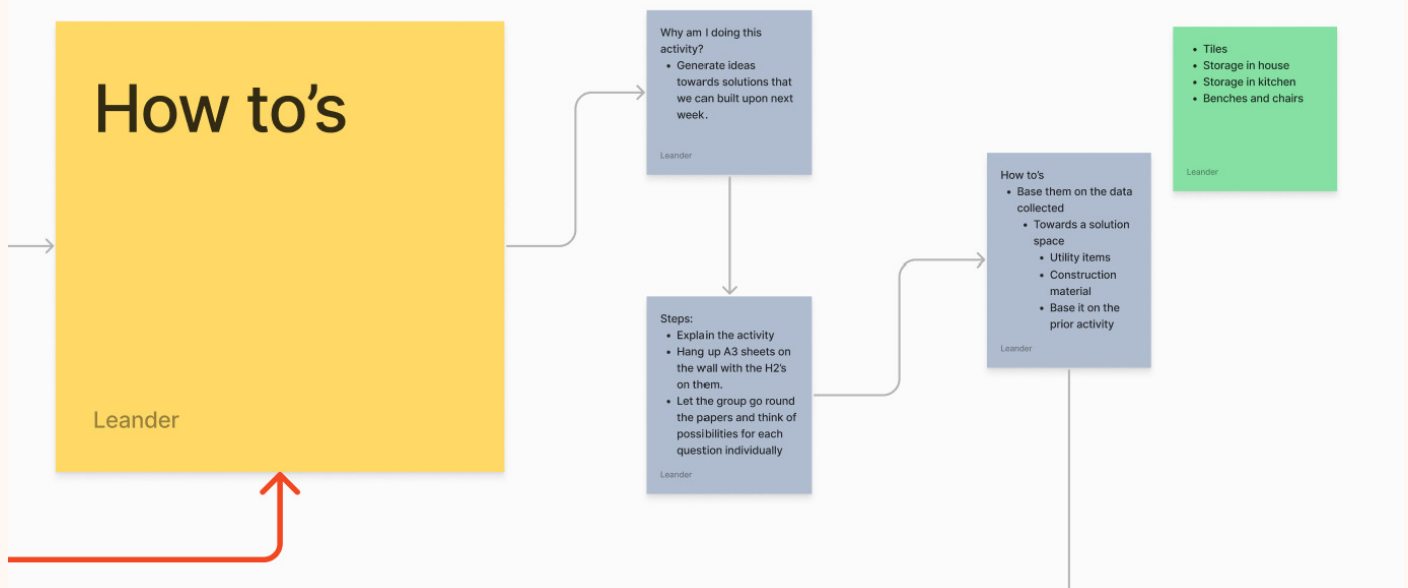
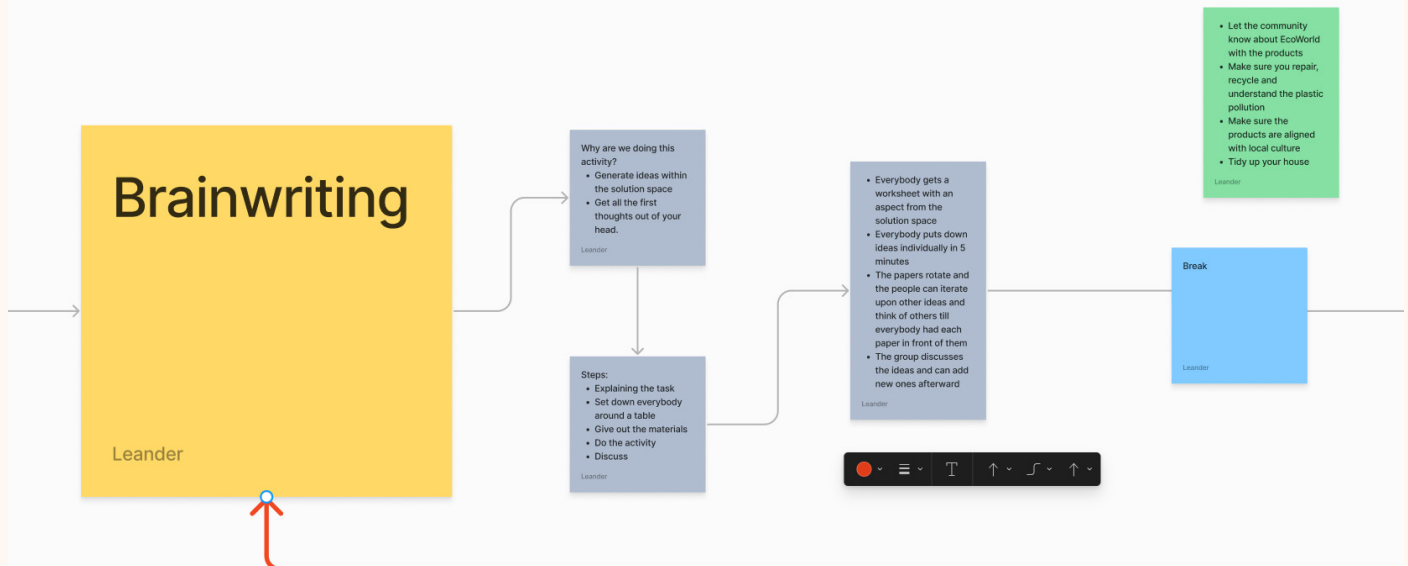
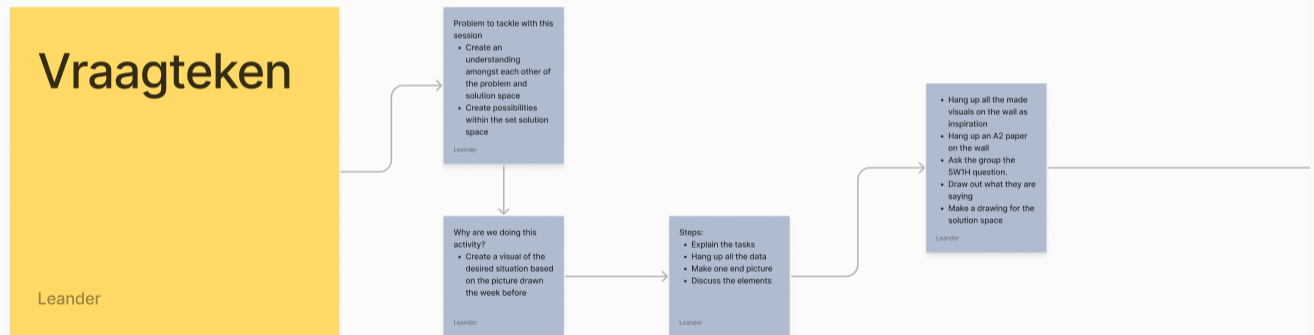


Creative session 2





Creative session 3



Restating the solution space

Leander

Why am I doing this activity?

- Finalize the last session to create a mutual understanding on where the solution to the problem lies

Leander

Steps:

- Explain the task
- Let the participants walk around all the data produced in the last weeks
- Use the SPARK method to choose which ideas spark the most interest
- Reflect upon the plastic perception and how they perceive the material now

Leander

- Let everybody restate the problem in their words
- Find the commonalities between the formulations
- Pick 1-3 formulations
- Does it cover the solution space that we came up with
- Which statement is best, using the SPARK method.

Leander

- Reflect upon the plastic material
- Did something change in your view of the material
- Do you see something in the solutions space and the material overlapping?

Leander

Materials:

- A2 Paper
- Markers
- Tape
- A3 Paper

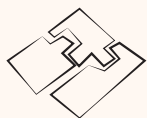
Leander

C. Concept Direction Pages

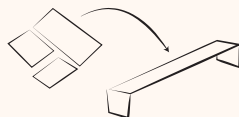


Concept Direction 1: Wall and Floor Tiles in Home

Initial Ideation Directions



Puzzle interlocking



Combine tiles and storage

Production method(s)



Sheet press



Injection moulding

Affordability

Market price = 2250 ksh per m² + 500 ksh laborcosts
 4 tiles can be made from 7 kg plastic
 Rough estimation of production costs: 838 ksh per m²
 Material costs = 7 x 15 ksh/kg
 Production labor = 110 ksh and hour/ 4 shelves an hour
 Production energy = 4 Kwh x 18 ksh/Kwh

Data for calculations found online and during the field trip to Watamu

Impact of the direction

Social impact

- Improve cleaning at home
- Creating job opportunities
- Eye catcher in house to spark awareness
- More affordable then current products
- Applicable in community places

Viable due to market potential and prove

Fit in the product life cycle

End of life possibilities

- Buy back system
- Easy to repair and modular parts

Work in Progress

Unstable walls to attach to
 More need from middle income



Concept Direction 3: Storage Facilities

Initial Ideation Directions



Open and simple design



IKEA/DIY approach

Production method(s)



Sheet press



Extruder

Affordability

Market price = 3000 ksh on average for wood and plastic products is around 2000 ksh
A shelf of 100 cm x 25 cm uses 7 kg of plastic
4 shelves costs 838 ksh to make, this can already result in a 2 layer cabinet.

Data for calculations found online and during the field trip to Watamu

Impact of the direction

Social impact

- Improve cleaning at home
- Creating job opportunities
- Eye catcher in house to spark awareness
- More affordable than current products
- Applicable in community places

Big market to expand in

Fit in the product life cycle

End of life possibilities

- Buy back system
- Easy to repair and modular parts

Work in Progress

Structural elements need to be sturdy



Concept Direction 2: Cleaning Utensils

Initial Ideation Directions



Stand out from the rest

Production method(s)



Extruder



Injection moulding

Affordability

Market price = 500-1500 ksh on average
To produce a sheet of 1 m2 it will cost 838 ksh.
From 1 m2 you can make a lot of these utensils

Impact of the direction

Social impact

- More affordable than current products
- Assists in cleaning, but does not improve

Market potential, clear need

Fit in the product life cycle

End of life possibilities

- Buy back system
- Easy to repair

Work in Progress

A lot of competition, satisfied market
Implications with micro plastics with food and water
Strength of the material and wearing off.

Data for calculations found online and during the field trip to Watamu

D. Explanation of Harris Profile 1

Tile scores:

Social impact:

- ++, hygiene improvement over long time and also other benefits to the living conditions in house
- +, new technology and product to develop, although very straightforward
- ++, Can be produced locally and from local material easily
- ++, Easy to scale up in production and cost of production can be relatively low
- ++, Can be seen in a lot of houses already when transition towards middle income, often the first thing that is bought

Environmental impact

- ++, Focus on long end of life and improving on the usage stage in the circular loop
- ++, long lasting product in house
- +, Floor tiles might need to be stronger, but primarily plastic waste is used
- , Once broken the end of life is found, but possibilities to explore prolonging the end of life

Company/business impact

- ++, new product which can ignite local enterprises
- +, an eye-catcher in-house that can spark conversation among users

Cleaning utensil scores:

Social impact

- ++, especially for low-income households this holds social value while creating durable and affordable products
- +, new technology and product to develop, although very straightforward
- ++, Can be produced locally and from local material easily
- +, Not as easy to scale up while there are many products within this category to focus on
- ++, This is among one of the basic needs for the local community

Environmental impact

- +, Creates social value, and focuses on the usage stage of the product life cycle but not the end of life
- , Product that often breaks in households and needs extensive improvement to create long lasting products
- +, Can be made from 100% plastic, but this can cause a shorter lifespan due to the usage of the products
- , Not easy to repair while they are very specific products, but possibilities to explore ways of extending the end-of-life

Company/business impact

- ++, new product which can ignite local enterprises
- , among all the other products in the house and will probably not inspire the users

Storage possibility scores

Social impact

- ++, hygiene improvement over long time and also other benefits to the living conditions in house
- ++, Inspiring new technology to discover for the local employees, also the construction can be interesting to learn about and use for future projects
- +, implementation can be a bit harder because of the building process but can be done locally
- ++, Cost of production can be relatively low, and especially in this category the alternatives are very expensive
- ++, designed together with the local community, and can be found in every household in Watamu

Environmental impact

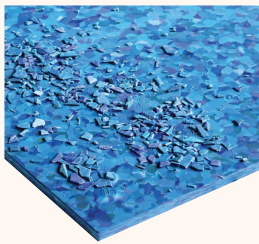
- ++, Focus on long end of life and improving on the usage stage in the circular loop
- ++, long lasting product in house
- +, parts of the product can be made from 100% plastic, the structural elements might need other materials too.
- +, many opportunities to create modular structures that can be repaired once broken

Company/business impact

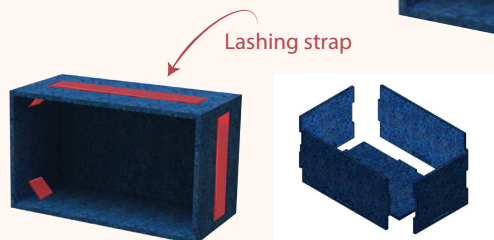
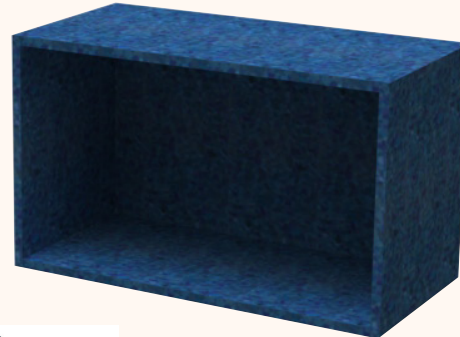
- ++, new product which can ignite local enterprises
- +, an eye-catcher in-house that can spark conversation among users

E. 3 Concept Pages

CONCEPT 1: BOX CABINET

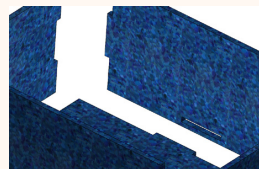


Material:
Polypropylene (PP)
~ 3 kg per box



Assembly Process

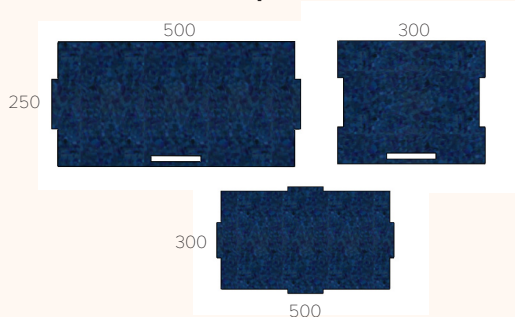
The components fit into each other. A lashing strap will hold it together providing strength



Manufacturing

The components are made with a sheet press and cut with a router from a 1x1 meter plastic sheet.

Components



Cost Estimation*

Collecting and Sorting: $15 \text{ (ksh/kg)} \times 3 \text{ (kg)} = 45$ ksh per box
Shredding waste: 12 ksh per box
Manufacturing Labor: $110 \text{ (ksh/h)} / 2 \text{ (box/h)} = 55$ ksh per box
Total = 112 ksh per box (excl. energy costs)
Market price = 350 ksh per box

Fit in the Context

This concept emphasizes modularity. The boxes can be used individually as storage containers or stacked to form a closet. They can also serve as transportation units or even chairs. This versatility caters to the practical and hands-on mindset of the end-users.

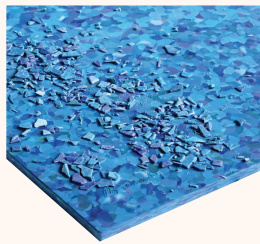
Circular Design

The assembly process focuses on minimizing permanent connections through sliding and a lashing strap, making disassembly for recycling straightforward. Additionally, this concept offers significant value to users through its versatility, raising awareness about the various possibilities with this emerging material.

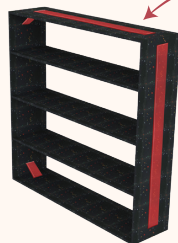


*Cost estimation data based on market research in Watamu

CONCEPT 2: SQUARE CABINET



Material:
Polypropylene (PP)
~23 kg per cabinet

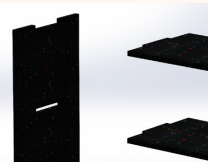


Lashing strap



Assembly Process

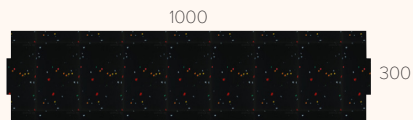
The components fit into each other. A lashing strap will hold it together providing strength



Manufacturing

The components are made with a sheet press and cut with a router from 3 1x1 meter plastic sheets.

Components



Cost Estimation*

Collecting and Sorting: 15 (ksh/kg) x 23 (kg) = 345 ksh per cabinet

Shredding waste: 12 ksh per cabinet

Manufacturing Labor: 110 (ksh/h) / 1 (cabinets/h) = 110 ksh per cabinet

Total = 467 ksh per cabinet (excl. energy costs)

Market price = 3000 ksh per cabinet

Fit in the Context

This concept focuses on a simple and recognizable shape, akin to a basic cabinet, yet avoids permanent connections. The components slide into each other and are secured with a lashing strap, creating a solid structure. Its practical and functional design fits well in the local context, ensuring easy adaptation.

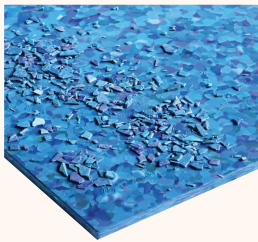
Circular Design

This concept highlights modularity and reparability by avoiding permanent connections. Users can freely choose the number and height of shelves, fostering a sense of ownership and extending the product's life through adaptability. Disassembly is also straightforward, allowing for the replacement of individual components instead of the entire structure at the end of its life.

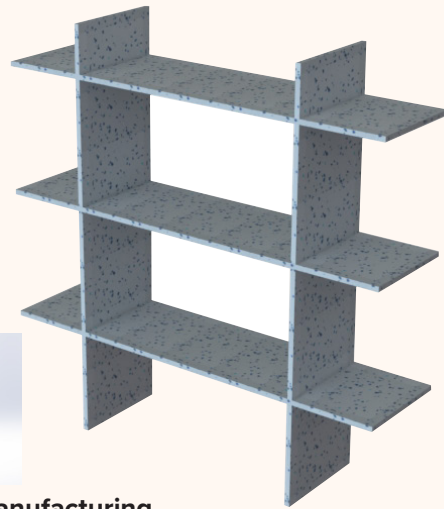
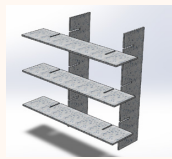
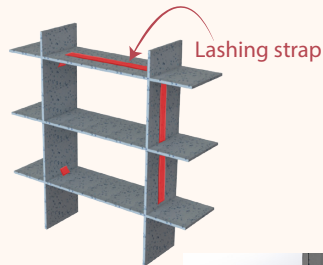


*Cost estimation data based on market research in Watamu

CONCEPT 3: TICTACTOE CABINET



Material:
Polypropylene (PP)
~15 kg per cabinet



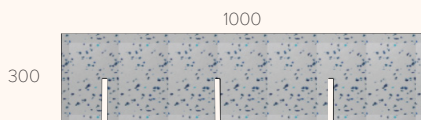
Assembly Process

The components slide into each other. A lashing strap will hold it together providing strength

Manufacturing

The components are made with a sheet press and cut with a router from 2 1x1 meter plastic sheets.

Components



Cost Estimation*

Collecting and Sorting: $15 \text{ (ksh/kg)} \times 15 \text{ (kg)} = 225$ ksh per cabinet

Shredding waste: 12 ksh per cabinet

Manufacturing Labor: $110 \text{ (ksh/h)} / 2 \text{ (cabinets/h)} = 55$ ksh per cabinet

Total = 347 ksh per cabinet (excl. energy costs)

Market price = 3000 ksh per cabinet

Fit in the Context

This concept emphasizes easy assembly and disassembly. Using a lashing strap, the construction remains solid yet accessible to local manufacturers and users. This simplicity facilitates the establishment of small and medium-sized enterprises (SMEs) selling this product. Additionally, the open and straightforward design allows users to easily access the contents of the storage facility.

Circular Design

This concept aligns with EcoWorld's circular design approach by prioritizing quick and easy assembly and disassembly, featuring easy sliding and no permanent connections. This results in a straightforward assembly process with minimal steps and clear sequences, ensuring access to all components at all times. The modular design enhances repairability, allowing users to replace individual shelves instead of the entire structure if something breaks.



*Cost estimation data based on market research in Watamu

F. Explanation of Harris Profile 2

Concept 1 (box) scores:

Fit in Context

- +, the box shape is simple, but using it as a cabinet is not recognized at first glance.
- ++, The box is very rigid, and can also be shaped in corners when stacked
- ++, Easy to produce from a sheet locally
- ++, The cost of the product will be lower than 2000 ksh
- +, It is not really an eye catcher on itself, also because of the other use cases

Functionality

- +, Functional, but not straightforward to use as a cabinet
- , The boxes will be too small for big pots
- ++, The product can stand on its own
- +, It is not easy to see what is inside of the box

Circular Design

- ++, it is very modular with a simple disassembly process
- ++, no permanent connections, which makes disassembling easy
- +, Because of the different use cases, the wearing of the product will be quicker
- +, There are a lot of different components which makes for a long process
- ++, It can be made from PP
- +, It needs something extra to start this process

Concept 2 (square cabinet) scores:

Fit in Context

- ++, A very straightforward and simple design, which is recognizable for the end users
- ++, a rigid design that can stand alone
- ++, It can be made from locally produced sheets
- ++, It will cost less to produce this product
- ++, This big closet will be an eye catcher in house

Functionality

- ++, Very practical design, where the use case is very straightforward
- +, Big closet, but not as easy to store all the different big pans
- ++, Due to the ground shelf, the product will be able to stand alone
- +, not as easy to access and see all the content because of the closed sides

Circular Design

- ++, It is a modular design due to the easy disassembly process
- ++, no permanent connections with limited components
- ++, A structure that will last for more than 1 year
- ++, The shelves are easy to replace
- ++, Can be made from PP
- +, It needs something extra to start this process

Concept 2 (TicTacToo cabinet) scores:

Fit in Context

- ++, A very straightforward and simple design, which is recognizable for the end users
- +, The small surface area on the ground can cause the product to tip over
- ++, It can be made from locally produced sheets
- ++, It will cost less to produce this product
- ++, this unique design will be recognizable, yet an eye catcher in house

Functionality

- ++, Very practical design, where the use case is very straightforward
- ++, the concept can store all different items because of the open design
- +, There is a danger of the product tipping over easily
- ++, the open design will enhance the functionality of the concept

Circular Design

- ++, It is a modular design due to the easy disassembly process
- ++, no permanent connections with limited components
- ++, A structure that will last for more than 1 year
- ++, The shelves are easy to replace
- ++, Can be made from PP
- +, It needs something extra to start this process

G. Questionnaire 1

Questionnaire: 3 different concepts



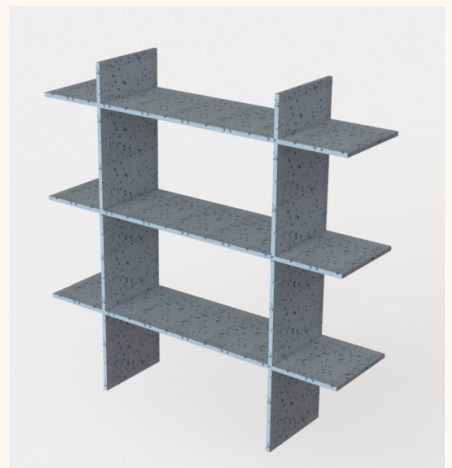
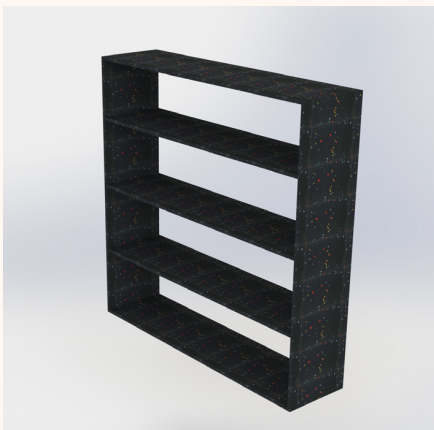
A.



B.



C.



Which shape of storage do you prefer, choosing A B or C, and why?

How would you use this storage in your house (kitchen utensils, eating and drinking utensils, clothing etc.)?

If your current cabinet breaks, would you consider buying this one and why?

How much would you be willing to spend on this storage possibility?

- A. 500 ksh
- B. 1000 ksh
- C. 1500 ksh
- D. 2000 ksh
- E. More than 2000 ksh, I would pay

Which color do you like best for the storage possibilities?

Do you prefer to assemble it yourself or have it pre-assembled?

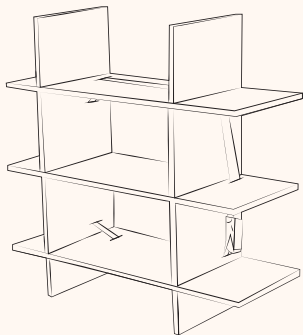
Do you think this shape is strong enough to hold your belongings? If not, why?

Do you trust this product (a lashing strap) used to connect the parts to be strong enough?

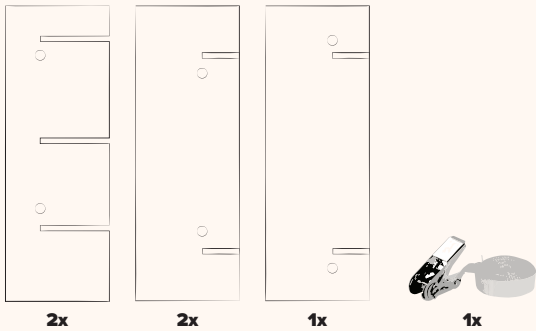


H. Assembly Manual

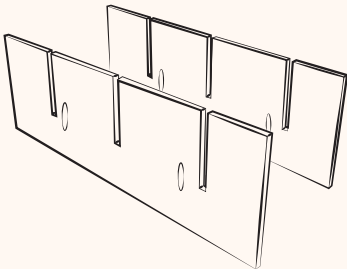
TTT CABINET



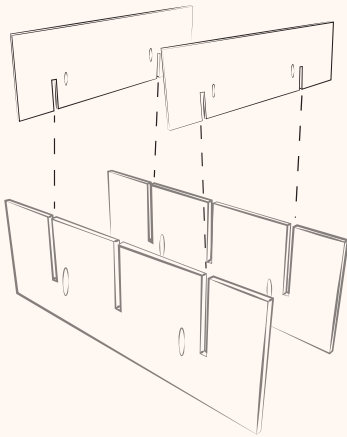
LIST OF COMPONENTS



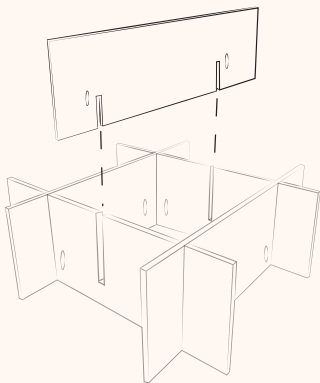
1



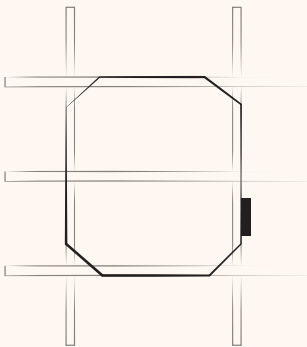
2



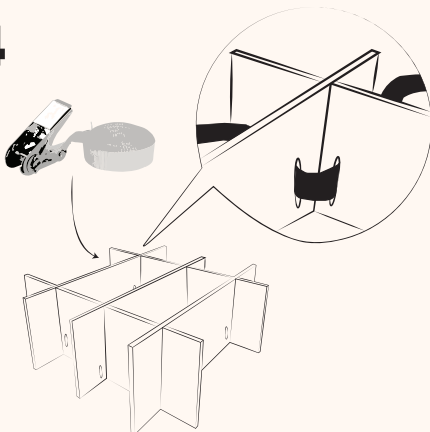
3



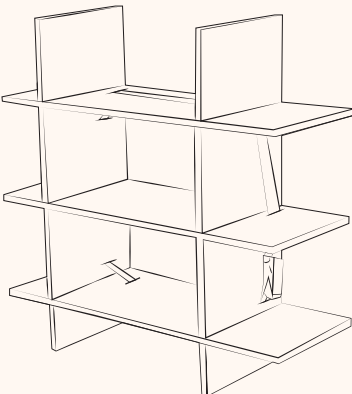
5



4



6



I. Questionnaire 2

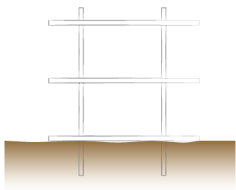
Questionnaire End-Users



Assembly Process

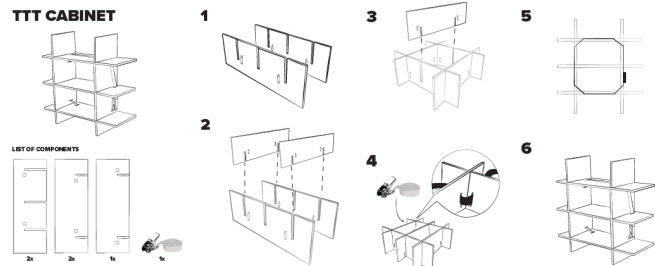
1. How familiar are they with the lashing strap and do you like the idea of using this product to make sure the product is secure and solid?

2. For safety, to prevent tipping over when climbed or bumped into the concept is dug in? What do you think of a cabinet being dug into the ground? Would you do this if you bought the product or would you skip it? How much do you value safety in a product?



3. Do you understand the assembly procedure, and do you think that you are able to put together this product yourself?

4. Would they like to receive this product pre-assembled, or disassembled?



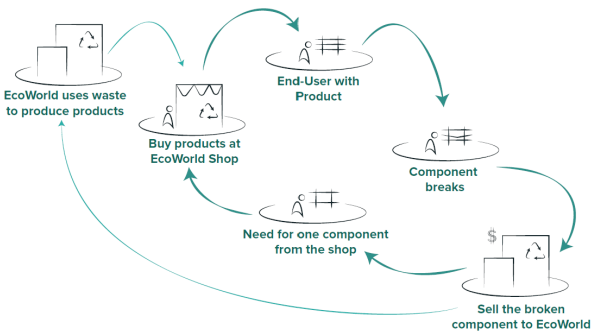
Shape and Functionality

1. What do you think of the shape, height and the width of the product?
(80 cm high, 100 cm long and 30 cm wide)
2. Would you say that this cabinet fits in your homestead, or how can it be improved to fit in more?
3. Do you trust the structure, how confident are you that this can store your stuff and that it is durable?
4. Are you willing to buy this product for 2000 ksh? (Try to sell it right now, why are they hesitant and how can they otherwise be persuaded)



Further Questions

1. Do you see the benefit of using plastic waste material and are you inspired by it? Would you tell their neighbors about the product and the benefits for people and planet?
2. Are you interested in this material being used for: Chairs, tables, benches, doors, windowsw etc.
3. Do you understand how this buy back scheme works? Do you understand what it means and would you use it to properly get rid of their products, instead of throwing it out in the environment

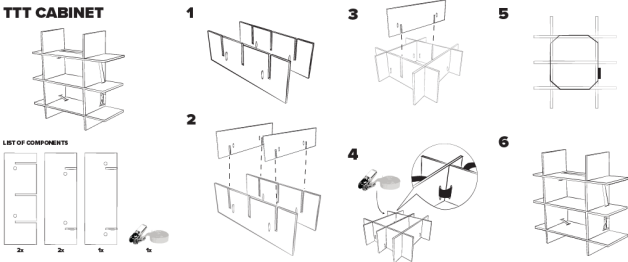


Questionnaire Employees



Assembly Process

1. Do you understand the assembly process, are there any questions or remarks on the built?



2. Do you have any structural comments on the design?

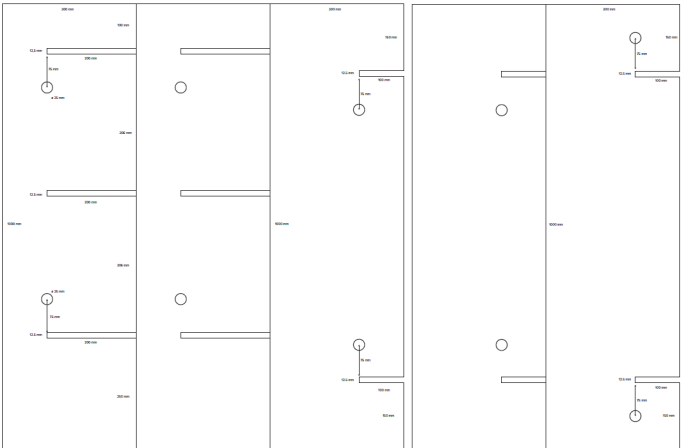
Production Process

1. Do you understand the different tools that are used during the production of this product, their use, limitations and possibilities.



2. Do you understand the template and how to built this template?

3. Do you see any hiccups or other possibilities within the production process?



Further Questions

1. Is this design and production process feasible at EcoWorld currently, or do you need different tools? How would you produce this concept currently?

2. Any other questions or remarks on the design to improve the production and overall strength of the concept?

J. Modelling Shelf

Study Report

Analyzed File	Load-case_leander v2
Version	Autodesk Fusion (2.0.19426)
Creation Date	2024-06-05, 16:41:44
Author	Leander Hombergen

Report Properties

Title	Studies
Author	Leander Hombergen

Simulation Model 1

Study 1 - Static Stress

Study Properties

Study Type	Static Stress
Last Modification Date	2024-06-05, 16:36:33

Settings

General

Contact Tolerance	0.10 mm
Remove Rigid Body Modes	No

Damping

Mesh

Average Element Size (% of model size)	
Solids	10
Scale Mesh Size Per Part	No
Average Element Size (absolute value)	-
Element Order	Parabolic
Create Curved Mesh Elements	Yes
Max. Turn Angle on Curves (Deg.)	60
Max. Adjacent Mesh Size Ratio	1.5
Max. Aspect Ratio	10
Minimum Element Size (% of average size)	20

Adaptive Mesh Refinement

Number of Refinement Steps	0
Results Convergence Tolerance (%)	20
Portion of Elements to Refine (%)	10
Results for Baseline Accuracy	von Mises Stress

Materials

Component	Material	Safety Factor
Body6	Steel	Yield Strength
Body5	Steel	Yield Strength
Body1	Polypropylene	Yield Strength

Steel

Density	7.850E-06 kg / mm^3
Young's Modulus	210000.00 MPa
Poisson's Ratio	0.30
Yield Strength	207.00 MPa
Ultimate Tensile Strength	345.00 MPa
Thermal Conductivity	0.056 W / (mm C)
Thermal Expansion Coefficient	1.200E-05 / C
Specific Heat	480.00 J / (kg C)

Polypropylene

Density	8.990E-07 kg / mm^3
Young's Modulus	619.00 MPa
Poisson's Ratio	0.45
Yield Strength	16.357 MPa
Ultimate Tensile Strength	19.701 MPa
Thermal Conductivity	1.980E-04 W / (mm C)
Thermal Expansion Coefficient	9.050E-05 / C
Specific Heat	2731.00 J / (kg C)

Contacts

Bonded

Name
[S] Bonded1 [Body1 Body6]
[S] Bonded2 [Body1 Body5]
[S] Bonded3 [Body1 Body6]
[S] Bonded4 [Body1 Body6]
[S] Bonded5 [Body1 Body6]
[S] Bonded6 [Body1 Body5]
[S] Bonded7 [Body1 Body5]
[S] Bonded8 [Body1 Body5]

Mesh

Type	Nodes	Elements
Solids	2113	944

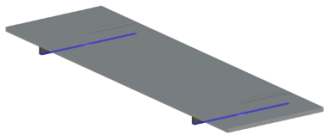
Load Case1

Constraints

Fixed2

Type	Fixed
Ux	Fixed
Uy	Fixed
Uz	Fixed

Selected Entities



Loads

Remote Force1

Type	Remote Force
Magnitude	200.00 N
X Value	0.00 N
Y Value	-200.00 N
Z Value	0.00 N
Position X	0.00 mm
Position Y	12.00 mm
Position Z	-150.00 mm

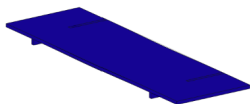
Results

Result Summary

Name	Minimum	Maximum
Safety Factor		
Safety Factor (Per Body)	15.00	15.00
Stress		
von Mises	0.003 MPa	3.183 MPa
1st Principal	-1.005 MPa	2.898 MPa
3rd Principal	-2.741 MPa	1.085 MPa
Normal XX	-1.93 MPa	1.341 MPa
Normal YY	-2.735 MPa	2.865 MPa
Normal ZZ	-1.065 MPa	1.083 MPa
Shear XY	-0.476 MPa	0.528 MPa
Shear YZ	-0.29 MPa	0.201 MPa
Shear ZX	-0.585 MPa	0.286 MPa
Displacement		
Total	0.00 mm	2.80 mm
X	-0.081 mm	0.081 mm
Y	-2.80 mm	0.002 mm
Z	-0.04 mm	0.033 mm
Reaction Force		
Total	0.00 N	144.49 N
X	-144.203 N	106.718 N
Y	-124.354 N	140.289 N
Z	-31.229 N	29.553 N
Strain		
Equivalent	2.472E-07	0.001
1st Principal	-6.958E-09	9.639E-04
3rd Principal	-0.001	-2.376E-08
Normal XX	-8.704E-04	8.820E-04
Normal YY	-8.325E-04	6.898E-04
Normal ZZ	-2.386E-04	2.518E-04
Shear XY	-9.125E-04	8.655E-04
Shear YZ	-3.550E-04	3.796E-04
Shear ZX	-3.671E-04	3.824E-04
Contact Pressure		
Total	0.00 MPa	2.88 MPa
X	-0.934 MPa	1.341 MPa
Y	-2.735 MPa	2.865 MPa
Z	-0.218 MPa	0.199 MPa
Contact Force		
Total	0.00 N	458.041 N
X	-263.503 N	265.322 N
Y	-313.258 N	366.568 N
Z	-70.949 N	50.452 N

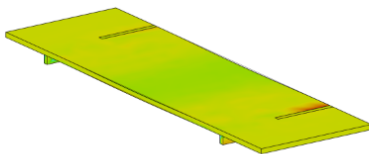
Safety Factor

Safety Factor (Per Body)
0.00 8.00



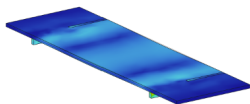
3rd Principal

[MPa] -2.741 1.085



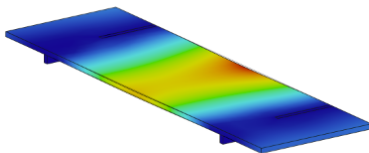
Stress

von Mises
[MPa] 0.003 3.183



Displacement

Total
[mm] 0.00 2.80



1st Principal
[MPa] -1.005 2.898

