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Master Thesis

Plastic Waste Recycling in Rural Africa: *Implementation of Plastic Waste Recycling Technologies Through Sustainable Business Model Development*

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Jeg bekrefter at arbeidet er selvstendig utarbeidet, og at referanser/kildehenvisninger til alle kilder som er brukt i arbeidet er oppgitt, *jf. Forskrift om studium og eksamen ved Høgskulen på Vestlandet, § 12-1*

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Alice Langseth

Abstract

Plastic waste pollution is a global problem, but it is especially prominent in most of Africa's rural towns. While there is research that investigates plastic waste management in Africa, there is a lack of research on how to implement sustainable solutions to increase the efficiency of plastic waste recycling. This thesis has been written to map different drivers and challenges to develop more effective and sustainable systems for plastic recycling in rural African Areas. This thesis aimed to answer the research question, *"How can business model innovation and technology adaptation increase the viability of plastic recycling in the informal waste sector in rural Africa?"*.

The research question was explored through a multiple-comparative case study. The three cases were a plastic recycling project in Uganda, Tanzania, and Mali. I personally participated in the project in Uganda, where data was collected through two field trips and qualitative interviews. Data for the two other cases were collected through qualitative interviews with project participants and document analysis. The data were analyzed through a framework for plastic waste management innovation that builds on a framework for responsible research. This framework comprises four dimensions, *territoriality, discourse, materiality, and organization.* The key findings from this study show that the waste management practices in rural Africa are poor, where PET and LDPE are common pollutants. Plastic waste is generally burned or openly dumped, causing negative impacts on both the environment and human health. There are structures in the informal waste sector for collecting, processing, and selling plastics, but they face challenges with a lack of equipment and capital to streamline their businesses. The projects have implemented different technological solutions and aim to develop profitable business models to increase the efficiency of plastic waste recycling.

The results from the analysis suggest that the adaptation of technological solutions to local conditions, production methods, and available resources can result in a long-term solution that increases the potential for successfully creating economic, environmental, and social value. The implementation of these recycling technologies should be paired with a sustainable business model to ensure production, viability, and profitability. Lastly, the framework for plastic waste management innovation is shown to be a beneficial tool in developing technological solutions and business models to ensure that they are suitable for local conditions.

Keywords: plastic waste management, plastic recycling technology, sustainability, business model development, rural Africa.

Sammendrag

Forurensning av plast er et globalt problem, men det er spesielt fremtredende i de fleste av Afrikas rurale byer. Mens det finnes forskning som undersøker plastavfallshåndtering i Afrika, mangler det forskning på hvordan man kan implementere bærekraftige løsninger for å øke effektiviteten av plastresirkulering. Denne oppgaven er skrevet med formålet om å kartlegge ulike drivere og utfordringer for å utvikle mer effektive og bærekraftige systemer for plastresirkulering i rurale afrikanske områder. Målet med denne oppgaven var å besvare forskningsspørsmålet *«Hvordan kan forretningsmodellinnovasjon og teknologitilpasning øke levedyktigheten til plastresirkulering i den uformelle avfallssektoren i rurale Afrika?»*.

Forskningsspørsmålet ble utforsket gjennom en multippel komparativ casestudie. De tre casene var et plastresirkuleringsprosjekt i Uganda, Tanzania, og Mali. Jeg deltok personlig i prosjektet i Uganda der data var samlet gjennom to feltturer og kvalitative intervjuer. Data for de to andre casene ble samlet gjennom kvalitative intervjuer med prosjektdeltakere og dokumentanalyse. Data ble analysert gjennom et rammeverk for innovasjon innen plastavfallshåndtering, som bygger på et rammeverk for ansvarlig forskning. Rammeverket består av fire dimensjoner, *territorialitet, diskurs, materialitet, og organisering.* Nøkkelfunnene fra denne studien viste at plasthåndteringspraksis i rurale Afrika er dårlige, der PET og LDPE er vanlige forurensinger. Plastavfall blir vanligvis brent eller åpent dumpet, noe som har negative konsekvenser for både miljøet og menneskers helse. Det finnes strukturer i den uformelle avfallssektoren for innsamling, prosessering og salg av plast, men de står overfor utfordringer med mangel på utstyr og kapital for å effektivisere virksomheten. Prosjektene har implementert ulike teknologiske løsninger og har som mål å utvikle lønnsomme forretningsmodeller for å øke effektiviteten av gjenvinning av avfall.

Resultatene fra analysen tyder på at teknologiske løsninger som er tilpasset lokale forhold, produksjonsmetoder og tilgjengelige ressurser kan resultere i en langsiktig løsning som øker potensialet for å lykkes med å skape økonomiske, miljømessige og sosiale verdier. Implementeringen bør kobles med en bærekraftig forretningsmodell for å sikre produksjon, levedyktighet og lønnsomhet. Avslutningsvis, rammeverket for innovasjon innen plastavfallshåndtering har vist seg å være et nyttig verktøy i utviklingen av teknologiske løsninger og forretningsmodeller for å sikre at de er egnet for lokale forhold.

Nøkkelord: plastavfallshåndtering, plastresirkuleringsteknologi, bærekraft, utvikling av forretningsmodeller, rurale Afrika.

Abbreviations and definitions

CBO – Community-based organizations

EWD – Engineers Without Borders

GIE – Economic interest groups

GSC - Grand Societal Challenge

HB – Human Brights Engineering

HDPE – High-Density Polyethylene

HSE – Health, Safety, and Environment

HSEQ – Health, safety, environment, and quality

LCA – Life cycle assessment

MSE - Micro- and small enterprises

MSW – Municipal solid waste

NGO - Nongovernmental organization

PE – Polyethylene

PET – Polyethylene terephthalate

POPs – Persistent organic pollutions such as pesticides, industrial chemicals, and unintentional by-products formed during industrial processes, degradation, or combustion.

PP – Polypropylene

PSWM - Participatory sustainable waste management

PWBC – Plastic waste business collector

RRI - Responsible Research and Innovation

S3A – Active Speed Schooling Strategy

SDGs – Sustainable Development Goals

SFC – Saving for Change

SSA – Sub-Saharan Africa

TBL – Triple bottom line

TLBMC – Triple layer business model canvas

UN – United Nations

WPO – Waste picker organizations

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1.0 Introduction

1.1 Purpose of Research

In collaboration with Human Brights Engineering (HB) and Engineers Without Borders (EWB), this research aims to map different drivers and challenges connected to developing more effective and sustainable systems for plastic recycling in rural African areas. The discovered patterns will be critical in developing technological solutions, business models, and increased resource utilization. The motivational factor behind this is to hopefully create a "best practice" that can be used within similar projects.

The contributions from this research can be a valuable tool for future projects aiming to implement sustainable plastic waste management solutions in a rural context. Further, I hope that my contributions can aid in creating new possibilities and economic incentives for plastic waste management while adding environmental and social value. In addition to reducing plastic pollution in the environment, another possible benefit could be the reduction of health hazards if more plastic waste were recovered and sold instead of openly burned.

1.2 Plastic Pollution

Plastic is a popular material that has become a part of many products in our everyday life, and it is hard to imagine a life without plastics. It has various properties, such as processability, resilience, recyclability, and versatility. With its lightweight and low cost, plastic is an attractive material that has gained popularity since World War 2, replacing expensive, scarce, and complex products (Shrivastava, 2018, p. 1). From an economic perspective, the invention of plastic has led to massive economic benefits through versatility and low production costs, and it is the workhorse material of the modern economy (World Economic Forum et al., 2016). Plastic production is expected to almost quadruple by 2050, but with an increased production and consumption rate, there will also be drawbacks.

Even though plastics are recyclable, only 14% of plastic packaging is collected for recycling. The remaining plastics are either incinerated, disposed on landfills, or leaked into the environment (World Economic Forum et al., 2016). With a production of about 400 million tons of plastic waste every year, the use of plastics comes with an expensive price tag of environmental, social, economic, and health consequences (UNEP, n.d.). The production of plastic waste is highly reliant on oil and gas, and it is estimated that around 7% of the world's oil production is used to make plastics. If the projection of plastic production is correct, this number will increase to 20% by 2050 (European Environment Agency., 2021). As a result,

climate change arises due to greenhouse gas emissions from oil and gas extraction. Other negative externalities are related to the abundance of plastic waste on land and sea and exposure to toxic substances by mitigating particle additives, impurities, and degraded chemicals. This has detrimental effects on wildlife and negative health impacts on humans and nature (European Environment Agency., 2021).

1.3 Plastic Waste Pollution and its Impacts in Africa

While plastic pollution is a global issue, it has caused massive impacts across the African continent. Most of Africa's rural towns are becoming heavily polluted with plastic waste. With inappropriate disposal and the lack of effective plastic waste management, this is a highly visible problem impacting economic, social, and environmental factors (Babayemi et al., 2019; Sadan & De Kock, 2021). In 2015 Africa generated 19 million tons of plastic waste, where the main fraction of 17 million tons was considered mismanaged. The global generation of mismanaged plastic waste was around 60-99 million tons in the same year, meaning that Africa is a huge contributor, with 17-28% of the world's mismanaged plastic waste. If plastic production and consumption continue in the business-as-usual scenario, these numbers are projected to triple by 2060 (Okot-Okumu, 2019). See Appendix A for additional waste projections and waste compositions.

The plastic pollution problem also causes implications for infrastructure. During heavy rainfalls, plastic pollution gets washed away, blocking waterways and drainage systems and leading to huge costs related to cleanups and repair (Sadan & De Kock, 2021). Furthermore, lacking infrastructure can also mean limited access to formal waste management systems. Due to this, many households resort to open dumping, open burning, and burial of plastic waste. This causes negative health impacts and the emission of greenhouse gasses, and damage to roads and other municipal infrastructure (Mpinda et al., 2016; Webster, 2018). Implications on ecosystems can be a result of plastic pollution in agricultural fields. This can cause implications for livestock, as research has shown that some animals end up dying from eating plastic, which will, in turn, cause negative consequences for societies that depend on agriculture and livestock for their livelihoods (Priyanka & Dey, 2018; Sadan & De Kock, 2021). The plastic pollution problem and its environmental impacts can be illustrated through the African plastic life cycle, which is described in Appendix B.

1.4 Relevance

As discussed, the plastic pollution problem results in huge impacts across the triple bottom line, and the generation of plastic waste is estimated to continue if we continue with business as usual. The current plastic waste management system consists of actors from both the formal and informal sectors. Still, it is insufficient to manage the massive amounts of plastics produced and disposed of. Some of the major problems are that virgin plastic is largely dependent on the fossil-fuel industry, producers are not held accountable for the end-of-life stages, single-use plastics and unsustainable business models, limited infrastructure and capacity for collecting and sorting plastics, a limited recycling infrastructure, and low profitability in the recycling sector and secondary markets (See Appendix C) (Sadan & De Kock, 2021). These problems will vary between countries and communities, and it is, therefore, crucial that we take an integrated approach to the problem where solutions can be tailored to unique needs.

In 2015 the United Nations implemented 17 Sustainable Development Goals (SDGs) as a universal call to end poverty, protect the planet, and ensure that people can live in peace and prosperity (UNDP, n.d.). More recently, on December 19th, 2022, the United Nations Biodiversity Conference ended with a climate agreement concluded between 196 countries. The agreement is an adaptation of the Kunming-Montreal Global Biodiversity Framework, which is meant to ensure the protection of at least 30% of the area in nature and oceans by 2030. Furthermore, 30% of all nature that has already been destroyed should be restored by 2030 (CBD, 2022). Combating the plastic pollution problem will therefore be an essential step to ensure that these goals are met.

Through an internship at Human Brights Engineering, I got the chance to take part in the SUWASO project, where I got to know the plastic issues in the rural town of Mityana, Uganda. The plastic pollution in Mityana is severe, and the existing structures of plastic waste management are ineffective. This is not only causing plastic pollution in nature and the waterways, but plastic waste is usually burned, resulting in toxic emissions that are a hazard to human health. Unlike most European countries, plastic waste collectors are not hired or paid to collect municipal plastic waste. Instead, informal plastic waste collectors travel around the city to buy plastic waste in the hope of reselling the most valuable plastics to other recyclers for a slightly higher price. Even though this system is insufficient, it opens new possibilities to create viable and sustainable business models with economic, environmental, and social gains.

1.5 Introduction to SUWASO

SUWASO, *Sustainable and Complete Waste Management Solutions for Rural and Semi-urban Environments,* is a project consisting of a partnership between The Norwegian Geotechnical Institute (NGI), Strømme Foundation, Human Brights, Engineers Without Borders, Norwegian Retailer's Environment Fund, and Rural Enterprise Development Solutions. Through this partnership, the project aims to expand the horizons of plastic waste management in rural and semi-urban contexts in developing countries, setting up a complete waste management system based on local conditions and markets (NGI, 2021). The projects consist of three subprojects: handling of plastic waste, organic waste, and residual waste. This research will only cover the handling of plastic waste.

The aim of the plastic subproject is to set up a waste management solution for plastic that should include collecting and sorting plastics, recycling the plastic into products with market value, and using technology that fits the local environment (NGI, 2021). This should be done through strong local context and collaboration throughout the process and by designing solutions that work in harmony with current plastic waste handling practices. Sustainability is a key factor, and long-term solutions are essential. The project, therefore, focuses on looking at different technical solutions to find the correct technological match for a plastic recycling facility based on local conditions.

2.0 Research Question and Clarifications

Through this research, I explore if the viability of plastic recycling can be increased through adaptation of technological solutions that are implemented through sustainable business models. Chapter 2 introduces the research questions and clarifications for this study. Relevant terms, models, and earlier research are presented in Chapter 3, which leads to a new analytic model used to answer the research questions. Chapter 4 then continues to present the methodologies and methods used during the research design and research process. Findings are then discussed through the analytical framework in Chapter 5 before conclusions are drawn in Chapter 6.

2.1 Research Question

In this project, I will explore how innovation can contribute to developing sustainable business models that create value in the economic, environmental, and social layers in rural African areas, where the focus is aimed at the adaptation of technological and systematic innovation

processes to local conditions. I wish to elucidate this matter by answering the following research question and two partial questions:

How can business model innovation and technology adaptation increase the viability of plastic recycling in the informal waste sector in rural Africa?

- *How can adaptation of technology to local conditions create value along the triple bottom line?*
- *How can sustainable business model development contribute to responsible implementation of plastic recycling technologies in rural Africa?*

By applying these questions to my collected data, I wish to explore whether the use of technological solutions can contribute to increase the viability and profitability of plastic waste recycling in rural Africa.

2.2 Clarifications

To answer my research questions, I will initially conduct a literature review to explore the current field of plastic recycling and waste management practices for the informal sector. The gap found in this literature review will be used to determine my need for data collection through the SUWASO project. Factors and aspects that will be discussed in this research will be limited to findings from the data collection phase. These findings will be analyzed through a theoretical framework including innovation theories, co-creation, responsible research, and the development of sustainable business models. I have chosen these theories as co-creation is a relevant factor for innovation and technology adaptation, while business development theory is relevant to determining how to best use this technology to increase sustainability and viability.

3.0 Theoretical Framework

This section explores existing research on waste management systems and plastic waste management in the context of rural Africa. To develop business models and technology to increase the viability of plastic recycling in the informal sector in rural Africa, it is important to acquire knowledge about the current practices. As an introduction, current waste management systems are examined before narrowing the search to rural areas and the role of the informal waste sector. The aim is to uncover which problem areas and challenges that have been elucidated through earlier research, in addition to practical solutions to these challenges. Further, key theories related to sustainability, business development, and innovation are presented before it is applied to the context of plastic waste management in rural Africa. This

chapter concludes with the development of a new framework that will be used for data analysis and answering research questions.

3.1 State of Plastic Waste Management in Rural Africa

3.1.1 Plastic Waste Management Practices

The average waste collection coverage is around 39-51% for low and lower-middle-income countries. In SSA, urban areas have a formal collection rate of around 43%, while it's only around 9% for rural areas. The uncollected waste is often managed individually by households, where statistics indicate that around 69% of waste is openly dumped or burned, around 4% is sent to landfills, and only 6,6% gets recycled or recovered (Kaza et al., 2018). The current waste management systems are inadequate to handle the amounts of generated waste, leading households to openly dump and burn their waste (Ayeleru et al., 2020). Poorer areas might not receive formal waste collection services at all, as waste collection in East African urban centers is based on income (Okot-Okumu, 2019). In addition, poor and rural areas often have poor road networks, reducing collection efficiency (Aryampa et al., 2019).

The waste management system consists of a formal and informal sector that takes place during the collection, transportation, and disposal of waste. The difference between these sectors is that the formal sector consists of actors regulated by the government, while all other actors are classified as informal. Typical waste collection methods include household collection by informal waste workers, collection from community points, and private collection for a fee. Other forms of collection happen through what is called a "summon to bring" system, where a truck is parked and summons people to deliver their waste. The waste is transported to the landfill using various trucks, but as these are uncovered, they often cause littering, odors, and aesthetics problems. The landfills receive a mix of waste, including hazardous waste. This makes the landfills a hazardous workplace, especially since most waste workers do not wear protective gear (Okot-Okumu, 2019).

The waste management services in rural areas are especially poor, with low collection rates and reliance on the informal sector. A significant amount of plastic waste in these areas is mainly managed through dumping and open burning, while some rural households practice reuse and recycling (Mihai et al., 2021). For the plastics that get recycled, this is mainly done through primary and secondary recycling (Ayeleru et al., 2020). Primary recycling is referred to as closed-loop recycling, where plastics are mechanically reprocessed into a product with equivalent properties (Bocken et al., 2016). Secondary recycling is another form of mechanical

recycling, often referred to as downcycling, where plastics are reprocessed into a “low” value product (Bocken et al., 2016). The mechanical recycling process happens through collecting, sorting, washing, and shredding plastic material before it is remelted and refabricated into new products. This type of recycling is currently gaining attention in plastic waste management as it can assist in minimizing the impact of plastic waste on the environment, in addition to creating economic incentives for certain actors (Ayeleru et al., 2020).

3.1.2 Informal Waste Sector

As we have seen, plastic waste management poses significant challenges in low and middle-income countries, including many African countries. This has led to the emergence of alternative ways to manage and dispose of waste through informal waste activities, which is referred to as the informal waste sector. This sector plays a significant role in recycling and reducing waste in landfills, which leads to a reduction of environmental pollution and therefore adds value to local communities. The creation of recycling markets leads to informal job opportunities that contribute to a reduction of unemployment while providing an additional source of income (Aparcana, 2017). The informal waste sector consists of actors such as waste pickers, collectors, and traders that are engaging in activities not recognized by the municipality. Different categories for informal waste recycling include street waste picking, itinerant waste buyers, municipal waste collection crews, and waste picking from dumps. The collectors sell their collected plastics to intermediaries such as traders or small junkshops, but are often poorly paid due to limited valorization (Aparcana, 2017; Wilson et al., 2006). Plastics, such as jerry cans, basins, plates, and bottles, are commonly recovered by informal waste pickers as these are suitable for mechanical recycling (Mihai et al., 2021; Okot-Okumu, 2019).

Different informal waste groups can be presented through a recycling trade hierarchy that shows the ability to add monetary value to the collected plastics. The value of the plastics is based on quality, which can be increased by sorting, cleaning, and processing. At the bottom of the hierarchy, there are individual pickers who are the most vulnerable. They do not have any organized networks to support them and are, therefore, easily exploited and poorly paid. Family-organized activities are common amongst dump scavengers and mainly vulnerable groups that consist of women, children, and elderly people. These groups have some level of social and economic support, reducing their vulnerability and risk of exploitation. When these waste workers are trained and organized into small or medium enterprises, they experience an increased ability to add value to collected materials. They create better organized networks and can enhance their position in the market. This also provides possibilities to negotiate with local

authorities or private sector actors, which in turn legitimizes their activities (Wilson et al., 2006).

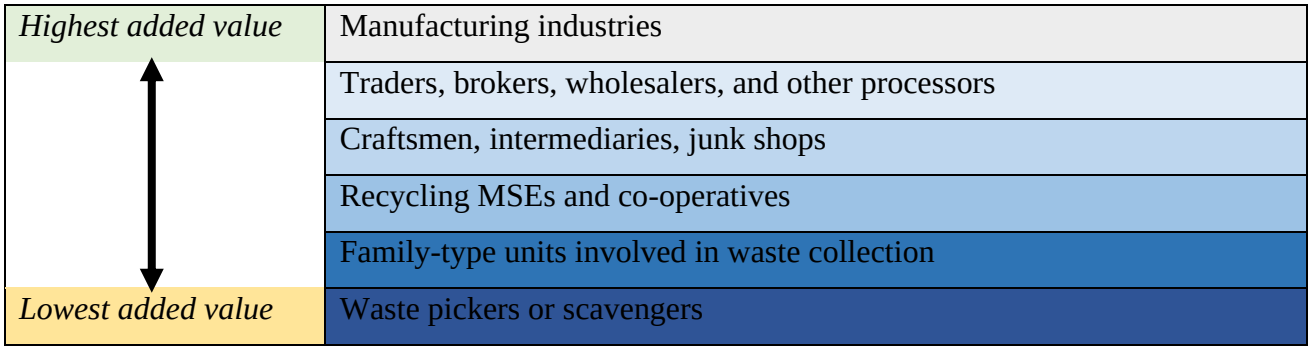


Figure 1 - Informal Waste Hierarchy (Wilson et al., 2006)

3.1.3 Challenges Within the Informal Sector

The activities performed by the informal waste sector result in both positive economic and environmental impacts, but research has also found multiple problems related to the sector. Some of the main problems are related to a series of social problems, such as poor working conditions, poor living conditions, child labor, and lack of education. In addition, citizens and authorities are often hostile toward actors in the informal sector. There are a lot of social stigmas related to informal waste workers, and they are often harassed by officials, exploited by intermediaries, and despised by society. This results in a lack of recognition and support which can make it difficult for them to organize and advocate for their rights (Aparcana, 2017).

For waste picker organizations, Kain et al. (2022) identify a variety of challenges as perceived by WPOs. One of these challenges is connected to resources, where there is a lack of initial capital and capital to grow, making the organizations unable to invest in suitable technology. If machines are donated, these often do not fit local requirements and therefore end up abandoned or broken. There is also a lack of formalization, with certifications and permits being scarce. Market-related challenges are also prevalent, where some include the inability to pay for waste collection services, competition between both groups and larger companies, lack of incentives, and commercialization. Other challenges are related to poor management, internal conflicts, and lack of group cohesion, and challenges related to a lack of knowledge and capacities on, for example, how to treat machines and how to reach retailers.

3.1.4 Suggestive Solutions for Plastic Waste Management Challenges

The main challenges within the plastic waste industry include limited infrastructure, lack of resources, inadequate policies, and weak enforcement. This can cause a culture of lassitude, which reduces the effectiveness of waste management systems (Debrah et al., 2022; Okot-

Okumu, 2019). The current waste management practices are not sustainable, especially considering that plastic waste that ends up in landfills can remain for up to 1500 years without degrading (Ayeleru et al., 2020). To combat these challenges, researchers have highlighted potential solutions, which include developing solutions tailored to local conditions, partnerships between stakeholders and civil societies, advocating for improved policies, and focusing on circular economy principles based on infrastructure limitations and appropriate technology (Aryampa et al., 2019; Ayeleru et al., 2020; Godfrey, 2019; Joshi & Seay, 2019)

3.1.4.1 Formalization of the Informal Waste Sector

Aparcana (2017) has suggested recognizing the contribution of the informal waste sector by taking a formalization approach to improving their working conditions and socioeconomic situation. Formalization refers to forming organizational structures with fixed rules and procedures. There are multiple approaches for formalization, where one is to establish contracts or cooperation agreements between municipalities and formalized waste workers organized in associations or cooperatives. An agreement may include performing certain tasks, such as collection services and recycling, while the income is based on the quantity and quality of recycled materials. Non-governmental organizations (NGOs) are often initiators and can supply technical, financial, and social help in the form of social aid projects. This approach has received critique as these kinds of projects aim to alleviate poverty but focus on social problems rather than recognizing the economic, social, and political contributions of the informal waste sector (Aparcana, 2017).

An alternative is to introduce participatory sustainable waste management (PSWM), which is defined as "*solid waste recovery, reuse and recycling practices with organized and empowered recycling co-operatives supported with public policies, embedded in solidarity economy, targeting social equity and environmental sustainability"* (Gutberlet, 2010, p. 171). This approach combines social and environmental goals by generating work and income from waste management activities and thus investing in human development and environmental health. PSWM is built on three pillars, governance and deliberative democracy, solidarity economy, and participatory management. These pillars are meant to ensure that political and social contexts in waste management are addressed, create synergies between stakeholders, and allow them to be involved in decision-making processes. This ensures that the responsibility of waste management is shared between government agencies and stakeholders, prevents overexploitation, and regulates fair access (Gutberlet, 2012).

Another approach for formalization is to organize recyclers into community-based organizations (CBOs) or micro- and small enterprises (MSEs). These organizations are formed when individuals organize themselves to perform waste services in their communities. This approach is typical for poverty-stricken areas with bad living conditions, high unemployment, and low legal and social status. The motivation behind this approach is often the opportunity to gain a source of income and the need to create a clean environment for their community. The municipality plays a minor role but supplies support by supplying regulations, equipment, infrastructure, and awareness. Income is usually generated through waste collection fees, either paid from the municipality or paid directly from the users. Alternatively, the formal waste sector can employ informal waste workers, although this approach neglects social and political factors (Aparcana, 2017). This is a typical approach in East Africa, where enabling measurements is the privatization of waste services. Barriers include a lack of business capacities and strategy, no financial sustainability, lack of support from local authorities, poor working conditions, and unwillingness or no possibility to pay for collection services (Aparcana, 2017).

The informal waste sector plays a key role in the waste management system in many African countries. Strengthening this sector can therefore improve waste management systems and livelihoods. Through this research, I wish to extend the research done on plastic recycling and the informal waste sector in rural African areas by taking a perspective that focuses on social problems as well as recognizing the economic, environmental, and social contributions from the informal waste sector.

3.2 Sustainability and the Triple Bottom Line

Sustainability is an idea that emerged during the 1980s and is often associated with the Brundtland Commission, which defined sustainability as "*development that meets our current needs without compromising the ability of future generations to meet their needs*" (Akinsemolu, 2020; Keeble, 1988). While this definition focuses on equality amongst generations, other definitions may focus on ecological aspects that respect the ability of nature to regenerate itself. From this standpoint, sustainability has been defined as "*a situation in which human activity is conducted in a way that conserves the functions of the earth's ecosystems"* (Geissdoerfer et al., 2017; ISO 15392, 2008). The concept's uptake can be traced back to the increasing evidence on global-scale environmental risks, which have been systematically investigated since the 1960s. These investigations raised questions if the current prosperity trends could be maintained in the future and revealed multiple tensions, such as asymmetrical access to resources and

scarcity, and implications of assimilative capacities of ecosystems over economic growth (Geissdoerfer et al., 2017).

Sustainability has later been linked to Elkington's (1997) concept of the *triple bottom line (TBL)*, which identifies sustainability as three different elements: profit, people, and the planet. The concept was coined from a business perspective, where Elkington believed that companies could be managed in a way that improves the well-being of people and the planet, in addition to earning profits. The triple bottom line has become a key framework in sustainability and is referred to as "*the balanced integration of economic performance, social inclusiveness, and environmental resilience, to benefit current and future generations"* (Geissdoerfer et al., 2017). Another concept worth mentioning is ESG, which stands for *Environmental, Social, and Governance.* This concept can be seen as an extension of the TBL, which is used to evaluate the sustainability and ethics of a company. This approach measures the procedures and operations of a company for the purpose of public accountability and investment opportunities (Armstrong, 2020).

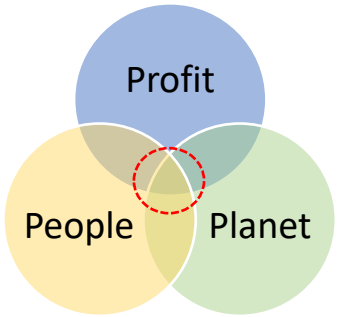


Figure 2 - The Triple Bottom Line (Elkington, 1997)

Sustainability opens the scope for multiple expectations on what should be developed, what should persist, for how long and for whose benefit. This raises questions about whether the current situation, here translated to resources, can be maintained in the future (Geissdoerfer et al., 2017). These are important questions to keep in mind to ensure that future solutions to environmental challenges, such as the plastic pollution problem, are sustainable and can create value across the TBL. The aim of this research is not to look for sustainable and ethical investment opportunities but rather to assess how innovation projects can develop and manage sustainable solutions. As a result, this research will focus on aspects of the TBL.

3.3 Responsible Research and Innovation

Innovation is a widely used term with various definitions, which often results in a poor understanding of what innovation really is (Meyer et al., 2022). One of the more well-known definitions originates from Joseph Schumpeter (1934), who defined innovation as a *new combination* of existing factors such as knowledge, resources, and technology. These new combinations can create five different types of innovations: new goods, new methods for production, new markets, new sources of supply of raw materials, and carrying out new organizations. Other scholars have defined innovation as a process that continuously finds new useful ways to re-organize the world (Meyer et al., 2022). Innovation can therefore be seen as a process where new combinations of knowledge and resources result in creating value. Today innovation has become a key activity for most businesses to create and maintain sustainable growth and competitive advantage (Viki et al., 2017).

Even though innovation can result in many positive outcomes, it can also cause negative externalities on the environment and societies (Jørgensen & Pedersen, 2019). These externalities may contribute to the Grand Societal Challenges (GSCs), such as the plastic pollution problem. GSCs are complex and multi-dimensional challenges that cannot be fully described or understood, are filled with uncertainty, and are laden with moral or social values. To successfully address these challenges, efforts from various actors, public, private, and non-profit, are required. To deal with these challenges, *Responsible Research and Innovation (RRI)* can be introduced as a framework that addresses both governance and evaluation of innovation and its externalities (Voegtlin et al., 2022). RRI is a relatively new term with multiple approaches from different perspectives. From a science and technology perspective, Von Schomberg (2013) proposes the following definition:

> *Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (to allow a proper embedding of scientific and technological advances in our society).*

The RRI literature contributes insight into how research and innovation can become more inclusive and sustainable, and it provides approaches and frameworks for reflecting on the societal impacts of research and technological development (Jakobsen et al., 2019). Owen et al. (2012) have presented an RRI framework consisting of three main features; democratizing the

governance of intent, institutionalizing responsiveness, and reframing responsibility. The first feature concerns the purpose and motivation behind science and innovation and how the targets for innovation can be identified in an ethical, inclusive, democratic, and equitable manner. The second feature is the need to establish mechanisms of reflection, anticipation, and inclusive deliberation in and around the process of research and innovation. The last feature is the need to reframe the concept of responsibility, not only for scientists, but also other actors such as innovators, policy-makers, and research funders (Owen et al., 2012). There are however multiple challenges and shortcomings related to RRI.

Von Schomberg (2013) argues that RRI needs to be addressed by various actors and institutions and that the most crucial advancement of RRI depends on how willing stakeholders are to work together toward socially desirable products. In addition, he argues that diverging ethical standards at the international level and "ethics-free" zones raises challenges and barriers to introducing RRI at a global level. As a result, Von Schomberg stresses the need to develop a global perspective on RRI and that RRI should become a "design" strategy that drives innovation in a direction toward achieving socially desirable goals (Von Schomberg, 2013).

Jakobsen et al. (2019) have raised critiques related to the RRI literature, claiming that the current framework is too narrow. They argue that RRI is a relatively immature and narrow area of inquiry that takes a top-down perspective and relies on standardized principles about public governance of research and innovation. They point out that literature lacks focus on how researchers, firms, and other actors perform responsible research and innovation. Further, the concept of RRI has mainly been used in the context of publicly funded research, meaning that there is a lack of awareness of how it can be performed in other contexts. To address these issues, Jakobsen et al. (2019) introduce an analytic model for a more context-sensitive perspective on responsible innovation by expanding the scope in two directions.

Their first contribution is to expand the narrow focus on the research processes to also consider how knowledge and new ideas are implemented and become responsible research-based innovations. Their next contribution is to include a broader spectrum of innovation processes, not only those that are exclusively research driven. This requires a more sensitive understanding of innovation where contextual circumstances are taken into consideration. In this scenario, contextual circumstances refer to how different factors such as technological specificities, industry sector characteristics, spatial or regional conditions, policy regulations, and socio-cultural dimensions form the setting of a practice (Jakobsen et al., 2019). Jakobsen et al. (2019) argue that context is an essential factor of the RRI framework as it highly influences how RRI

progresses. This is explained by the dynamic and interactive features of innovation processes and how they are situated in different contexts. Different contexts provide different drivers and challenges within the innovation process, also including how to ensure responsibility.

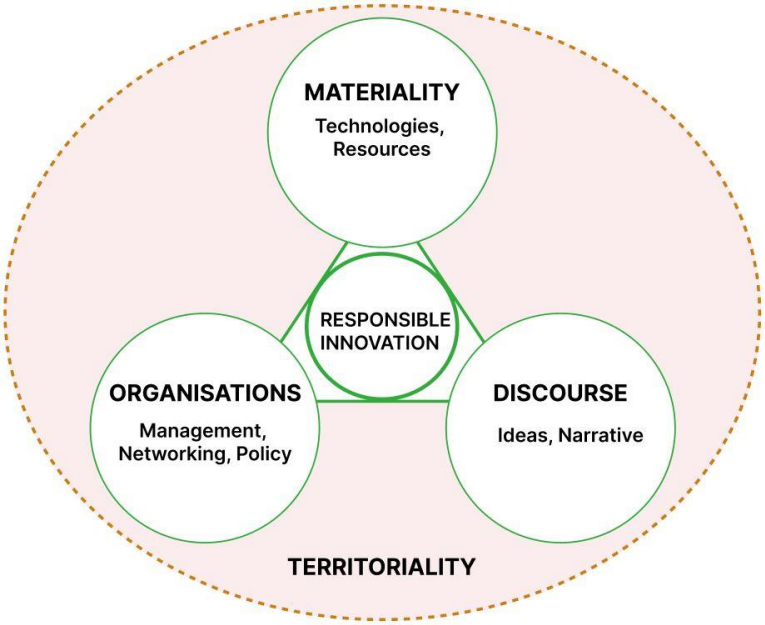


Figure 3 - The Responsible Innovation Complex (Jakobsen et al., 2019)

Figure 3 shows Jakobsen et al. (2019) analytic model for a context-sensitive understanding of responsible innovation. In this model they have chosen to focus more on responsible innovation, rather than research. Responsible innovation is here defined as innovation that meets all economic, social, ethical, and environmental goals. The (responsible) innovation processes should be analyzed through socially constructed complexes consisting of three dimensions: materiality, organizations, and discourse. The first dimension, materiality, includes aspects related to technology, infrastructure, and natural resources. The organizational dimension addresses management, modes of organizing, networking, and policy frameworks. The discursive dimension concerns the knowledge that lies behind the innovation. This dimension addresses the ideas behind the innovation, its narrative, what it should be, and how it could become a responsible innovation. Lastly, the model contains a territorial dimension that addresses the geographic complexity of the innovation, referring to scopes of actions and contingencies that often are conditioned by former practices and choices.

This model indicates which criteria must be met for an innovation to be considered responsible, which factors that should be assessed, as well as how different contexts can impact the innovation processes. On the other hand, it does not show how to design the innovation process

or how to manage a range of factors to ensure that the innovation becomes responsible. This model creates the fundament for the framework presented in Chapter 3.7.

3.4 Social Innovation Through Co-Creation

As discussed in Chapter 3.1.4.1, research has suggested that formalizing informal waste sector groups can increase their efficiency, make them follow health and safety regulations, and protect them from exploitation. However, this is not unproblematic, as previous research implicates that formalization causes conflicts between informal and formal waste collectors (Achankeng, 2003). Other researchers have found that these conflicts can be avoided if urban councils formalize all waste management activities with a clear set of rules (Okot-Okumu, 2019). Other ways to avoid or reduce these kinds of conflicts are through social innovation and co-creation.

Voorberg et al. (2015) define social innovation as "*the creation of long-lasting outcomes that aim to address societal needs by fundamentally changing the relationships, positions and rules between involved stakeholders, through an open process of participation, exchange and collaboration with relevant stakeholders, including end users, thereby crossing organizational boundaries and jurisdictions".* It is further specified that the participation of end users is indicated as co-creation. When this is applied to a public context, the end-users are citizens, meaning that citizens are a key part of the co-creation of public services that meet their needs. Voorberg et al. (2015) further present three different categories of co-creation based on the degree of citizen involvement. The first degree is the citizen as the co-implementer of public services. With plastic waste in mind, this can be described through the citizens sorting their waste before disposal and this way, only performing partial implementation tasks. The next degree is the citizen as a co-designer, meaning that the citizen plays a role in how the public service delivery should be designed. Again, from a plastic waste management perspective, this can include designing new sorting and collection systems that are accessible and easy to use. The last stage is the citizen as an initiator, which the government follows. Here the formalization of informal waste workers is a notable example. Citizens have taken the initiative to better waste management systems through the creation of informal jobs, and the government can follow by formalizing these groups.

Some of the objectives of co-creation are to gain more effectiveness, better efficiency, and improve customer satisfaction in public services (Voorberg et al., 2015). Through social innovation and co-creation, governments can therefore embrace citizen engagement to

overcome challenges and restore trust and satisfaction with government and politics (Brandsen et al., 2018). Further, there are organizational- and citizen factors and barriers that influence the level and quality of co-creation and its objectives. On the organizational side, these include the compatibility of public organizations to citizen participation, the attitude of public officials to citizen participation, risk-averse administrative culture, and clear incentives for co-creation. From the citizen side, these factors include citizen characteristics, customer awareness, presence of social capital, and risk aversion by citizens (Voorberg et al., 2015). Potential barriers can be overcome by, for example, creating policies that support co-creation from the organizational side. From the citizen side, barriers can be overcome by lowering participation costs, providing financial support, or inviting policies that create feelings of ownership (Voorberg et al., 2015).

Co-creation of public services can result in positive effects such as increased trust in government, empowerment of citizens, and increased service quality and effectiveness. Still, it is important to note that co-creation also can have negative effects. For example, even if the goal is to increase the benefits of public services, they might be altered in a way that restricts access for vulnerable groups, resulting in a loss of benefits (Brandsen et al., 2018). Social innovation and co-creation are likely to be key factors in formalizing the informal waste sector by including actors from both formal, informal, and private sectors. By including actors throughout the waste hierarchy, services and technology can be developed to fit the needs of both organizations and citizens, and this way creates benefits on an economic, environmental, and social level. This way there is a possibility to use co-creation as a tool to develop technology that can increase efficiency in plastic waste management, while it is also adapted to local needs. This can also result in the development of knowledge and capabilities to support and further develop technology, ensuring long-term operations. Researchers have also mentioned the need to implement circular economy principles to ensure the sustainable development of services (Ayeleru et al., 2020; Joshi & Seay, 2019; Mihai et al., 2021). To move towards a more circular economy, it is necessary to develop new and more circular business models throughout the value chain so that they can interact and thrive (Bocken et al., 2016). This means that co-creation is also useful in this context, as multiple actors can develop innovative solutions through collaboration.

3.5 Innovation Processes and Development

Innovation processes, often referred to as *the innovation journey*, can be defined as the step-by-step process where businesses create and capture value from an idea. These processes are

usually not easy or linear, and each process may face its own set of unique challenges (Tidd & Bessant, 2020, p. 71). There are multiple variations for how an innovation process could look, but Tidd and Bessant (2020) have pointed out some key stages that should be included: searching, selecting, implementing, value capturing, and learning.

The first stage involves *searching* for elements in an organization's internal and external environment that could signalize both opportunities and threats for change. The next step is to *select* which of these signals to respond to. The *implementation stage* involves the translation of these signals into ideas that leads to an innovation that can be launched in a market. This is an iterative step that requires problem solving skills and continuous environmental feedback. If the implementation stage is successful, the organization must capture value by ensuring adaptation and diffusion of the innovation, in addition to sustaining and growing its market position (Tidd & Bessant, 2020, p. 72). Each step in the innovation process requires its own set of knowledge and capabilities, and moving through the process will result in learning opportunities (Meyer et al., 2022). Knowledge and capabilities developed can then be recycled back into the innovation process, improving the ways in which the process is managed (Tidd & Bessant, 2020, p. 72).

The process describes the main stages of how an organization could build an innovation strategy, but it does not describe how to convert ideas into new innovations. Innovation can be divided into four different types: product innovation, process innovation, position innovation, and paradigm innovation. *Product innovation* refers to both new radical products and modified or improved versions of existing products. *Process innovation* refers to new ways of creating, delivering, and offering value. *Position innovation* concerns opening new market segments or radical shifts in markets, while *paradigm innovation* concerns rethinking or radical shifts in business models and mindsets (Tidd & Bessant, 2020, p. 75). The development of the different innovation types can be described through its own processes for product and service development, and the most suitable process should be tailored to each individual project. To facilitate the successful development of products, services, or business models, it is suggested to operate some form of structured staging process with set criteria at each stage (Ibid, (2020, p. 351).

3.6 Business Models for Sustainability

A business model can easily be summed up as a model that describes how an organization creates, delivers, and captures value, making it easy to define and communicate a specific

business idea (Osterwalder et al., 2010). With the plastic pollution problem and other sustainability issues, there is a need to tackle the pressing challenges for a sustainable future. Business model innovation through the development of more sustainable business models can be a great tool for a solution, and they are an important factor for sustainability as they can coordinate both technical and social innovations with system-level sustainability (Bocken et al., 2014).

Sustainable business model innovation is usually caused by two main drivers; the responsibility to attend to one's own negative externalities or the opportunity to attend to others' negative externalities (Jørgensen & Pedersen, 2019, p. 27). Externalities are defined as "*when the consumption or production choices of one person or firm enter the utility or production function of another entity without that entity's permission or compensation"* (Kolstad, 2011, p. 87). This means that externalities can result in effects across all aspects of the triple bottom line, making truly sustainable business models more complex. The development of sustainable business models can address these externalities by creating value on both an economic, environmental, and social level. To facilitate this, the *triple layer business model canvas* by Joyce and Paquin (2016) can be a helpful tool.

The *triple layer business model* canvas is an extension that builds on Osterwalder et al. (2010) *business model canvas* (BMC). Joyce and Paquin (2016) describe the TLBMC as a tool and framework that supports visualization, communication, and collaboration around innovating sustainable business models. Both the BMC and the TLBMC are visual tools, and visualizing different elements can facilitate discussions and exploration of new improvements, value creation impacts, and innovation. While the BMC focuses on the economic layer of a business model, the triple layer business model canvas (TLBMC) is a multi-layer canvas that adds environmental and social value creation into the business model (Joyce & Paquin, 2016). The environmental layer builds on a product or service life cycle assessment (LCA) and addresses the impact the product or service has on the environment throughout its lifetime. Similarly, the social layer builds on a social LCA and addresses how the organization affects its stakeholders. Ultimately all the layers are integrated into one model that supports the TBL perspective of organizational impact.

The economical layer of the business model canvas communicates a business' activities for value creation, delivery, and capture. This includes their customer segments, value propositions, channels, customer relationships, resources, key activities, key partners, and financial performance. The economic layer can be described as a tool to ensure that operations

are financially viable and provide profit for owners and stakeholders. Further, the layer can be used to assess a business's competitive advantage and the strategies it uses to differentiate itself from its competitors (Osterwalder et al., 2010). One of the main incentives behind a business model is to illustrate how a business can make strategic choices to create, capture, and deliver value. It is therefore beneficial to first determine a customer segment and explore how the business' value proposition can create value for the customer. During this assessment, the *Value Proposition Canvas* can be a helpful tool to map the customer profile and assess how to fulfill their needs (Osterwalder et al., 2014).

The environmental layer builds on the nine blocks from the economic layer by assessing environmental impacts from the production, delivery, and use phases of the value. This layer looks at the resources or materials a business uses, its production activities, functional value, distribution, and impacts from the use-phase and end of life. This way the environmental layer creates an overview of the business' positive and negative environmental impacts (Joyce & Paquin, 2016). The environmental layer can therefore be used as a tool to ensure that operations are sustainable by reducing environmental impact and preserving natural resources for future generations.

The last layer is the social layer, which includes social value and benefits for stakeholders, employees, governance components, relationships with suppliers and local communities, societal culture, and scale of outreach. These components make up the total social impacts and benefits caused by business operations. This layer is therefore used as a tool to assess how the business affects the people and communities it serves, as well as the broader society (Joyce & Paquin, 2016). These are all important aspects to include when developing business models for more sustainable and efficient plastic waste management systems. Lastly, it is important to note that the development process of a business model will never be complete. A business environment is prone to change, and aspects of the business model need to be adjusted to these changes to ensure its viability (Osterwalder et al., 2010).

The TLBMC is a great tool for visualizing how to create, capture and deliver value on an economic, social, and environmental level, but it has several shortcomings. This model alone does not show the intentions or narratives behind the business model, nor does it show the external environment and conditions where it plans to operate. There is also a lack of technological perspective as there are no indicators to show whether the applied technology in key activities is appropriate, if there is a need for adaptation to local conditions, and if so, how to proceed. There is a need for a more holistic framework to assess how business model

innovation and technology adaptation can increase viability of plastic recycling in the informal waste sector in rural Africa.

3.7 A Framework for Plastic Waste Management Innovation

The purpose of this research is to examine how business model innovation and technology adaptation can increase viability of plastic recycling in rural Africa by assessing value creation from both technology and business models across the TBL. To elaborate on this matter, this chapter has presented relevant theories related to plastic waste management in rural Africa, sustainability, innovation and innovation processes, and business models.

With a basis in Jakobsen et al.'s (2019) RRI-framework and Von Schomberg's (2013) claim that RRI should be a design strategy to direct innovation toward desirable societal goals, I have developed a new analytical framework that shows how the RRI-dimensions can constitute such a strategy, see figure 4. The framework consists of the four main dimensions from Jakobsen et al.'s (2019) framework, and RRI is defined as "*a responsible innovation project that creates value across the triple bottom line*". Each dimension is extended to include development aspects of business models- and technological innovations, in addition to being adapted to the context of plastic waste management in rural Africa. By defining RRI as an innovation project, one creates a set of criteria that must be met to be responsible and factors that must be considered. When including the tools for business and technology development, the framework is extended to include how to innovate and how to manage numerous factors to ensure responsibility. This creates the opportunity to develop innovative design strategies that are adapted to each individual project and its contexts.

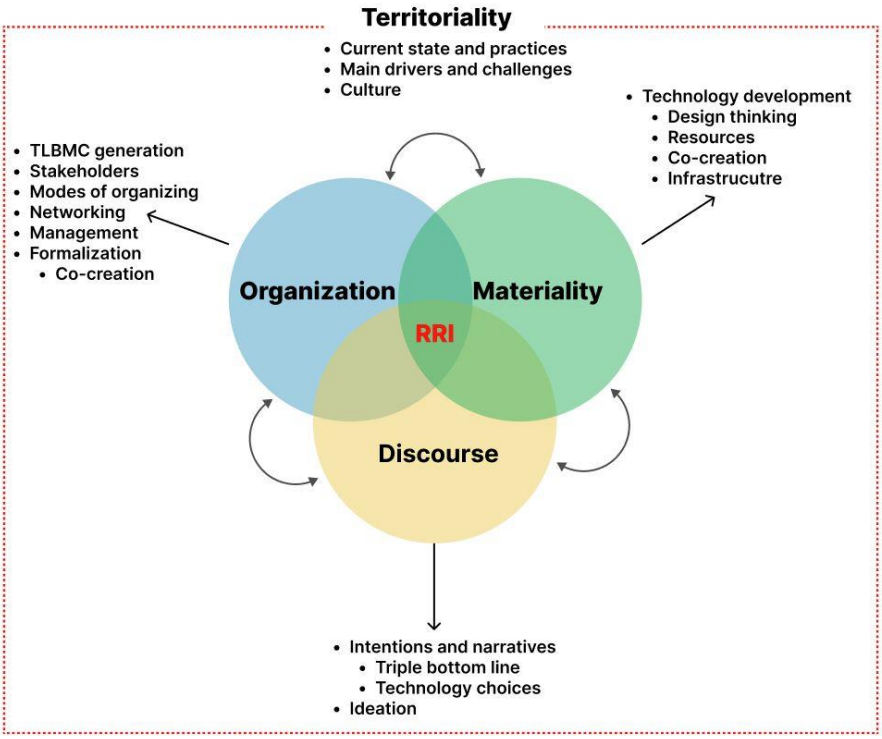


Figure 4 - Framework for Plastic Waste Management Innovation

The first dimension of the framework involves deciding the innovation project's territoriality. The purpose is to gain a valuable overview of the local context in which the project will run. This can be done through interviews and/or baseline studies to map the current plastic waste situation, current plastic waste management practices, main drivers for handling plastic waste, main challenges related to plastic waste, and other market research, such as assessing relevant costs and prices. Key elements may include assessing the plastic waste composition, degree of plastic pollution, geographical hotspots for waste generation and disposal, involvement from the municipality, use of formal and/or informal waste sector, and current practices related to collection, sorting, transportation, processing, and final disposal. Another important aspect is to assess drivers for plastic waste management, various challenges different stakeholders may experience, and cultural norms that need to be considered. This insight will help projects gaining contextual knowledge and therefore play an important role in creating value for stakeholders through both the technological and business model innovation processes (Hasso Plattner, n.d.; Joyce & Paquin, 2016).

Like the model from Jakobsen et al. (2019), the next dimension is related to the discourse and knowledge behind the project. A natural starting point is to define the intention behind the project and to assess if this is aligned with the TBL. To ensure value creation across layers, it is beneficial to determine certain criteria that should be fulfilled. Examples of such criteria can

include a need to be viable financially, increase local living conditions, reduce plastic pollution, or create jobs for the local community. The next aspect of this dimension is to ideate how to achieve the set criteria. This phase should be supported with insight from other dimensions of the framework, ensuring that local conditions and available resources are considered in decision-making processes. It is also important to discuss other aspects that might arise during the project work, such as technological decisions. While the choice of some technological solutions may seem like an excellent choice in the short term, other choices may contribute to greater value creation on the social and environmental layer, leading to additional value creation across the TBL in the long term.

The materiality dimension concerns the innovation process related to technology development or adaptation based on available resources and infrastructure. To ensure that development and adaptation of technology create solutions that meet the needs of end-users, as well as value creation across the TBL, co-creation through stakeholder involvement can be applied to the innovation process. This can also be an effective tool to reduce challenges met by the informal waste sector, as co-creation may reduce conflict and restore satisfaction and trust. Based on these factors, the design thinking method is highly suitable for the innovation process as it focuses on the end-users, enabling innovation through co-creation and stakeholder involvement, see Appendix G.

The organization dimension is extended to include the development of business models, in addition to modes of organizing, networks, and management, as these aspects are interrelated. The business model visualizes value creation and frames the sources of effectiveness, efficiency, agility, and strategic domain. The role of management and modes of organizing is to facilitate control and coordination based on the elements of the business model and its underlying value configuration (Fjeldstad & Snow, 2018). As the goal of a sustainable business model is to create value across the TBL, stakeholders play an important part in ensuring that the value created meets their needs. In waste management practices, it is therefore important to distinguish between the formal and informal sectors, as these may have different needs and perspectives. This makes the TLBMC a useful tool as it explores sustainable business model innovation while it includes a stakeholder perspective (Joyce & Paquin, 2016). New business models often involve new collaborations, networks, and relationships, and both co-creation and approaches to formalization could be relevant tools to increase efficiency and social value, and to create long-lasting outcomes that address the local societal needs.

The four dimensions are interrelated, and changes in elements of one dimension will affect elements of other dimensions. When developing a responsible innovation project, one should therefore iteratively assess elements of all dimensions during the development process, as changes may cause ripple effects throughout the whole framework. When seeking to develop a responsible innovation project, a natural starting point is to map and gain insight into the territoriality of the project. In the discourse dimension, it is advised to define the key intentions and narrative behind the project and use the knowledge gained from the previous dimension to discuss ideas and potential solutions. This creates a foundation for the innovation process of developing technological solutions and business models. In practice, one may assess several or all dimensions simultaneously rather than individually, and new insight from one dimension can result in the creation of new ideas, challenges, or changes across all dimensions.

This framework constitutes the analytical framework used in discussing the findings of this research. The aim is that this model will illustrate how the three different cases have proceeded to develop their projects, and this way elucidate their strengths and weaknesses. Materiality will be an important aspect to assess how technology has been adapted to the project's territoriality, while the organizational dimension assesses how the technology is used in a business model to create value across the TBL. These findings will be a key element in answering my research questions. Lastly, I hope that the developed framework and findings can add to the existing literature by providing a tool that can be used for developing future responsible innovation projects within plastic waste recycling.

4.0 Methodology

4.1 Research Design and Approach

When conducting research there are multiple ways to strategize how to best answer a research question. This can be referred to as a research design (Silkoset et al., 2021, pp. 68–69). The design implies a description of how the study should be conducted, what data to collect, and how the data should be analyzed to answer the research question. Some of the most known designs are *explorative, descriptive, and explanatory* designs. When choosing a design, it is pragmatic to base the choice on existing knowledge about the research area and ambitions to analyze and explain correlations.

This research aims to answer the following research question "*How can business model innovation and technology adaptation increase viability for plastic recycling in the informal waste sector in rural Africa?".* This was answered by examining how adaptation of technology

to local conditions can create value along the triple bottom line, and how development of new business models can increase viability and resource utilization. In this research, I explored current incentives, waste management practices, available resources, and main challenges, both through desk research and data collection through interviews and fieldwork. The findings were analyzed through the framework presented in Chapter 3.7, which creates the fundament for answering my research questions.

There are some limitations to existing research regarding plastic recycling in rural Africa. There is limited data regarding plastic waste management for specific areas, especially when it comes to rural areas. Research has elucidated several challenges related to plastic waste recycling and potential solutions, but this is researched as isolated incidents and not as a holistic system. Further, there is a lack of research that combines both business model creation and plastic waste management in rural Africa. This research explored plastic waste management as a more holistic system and was therefore conducted through an explorative design. Explorative research designs seek to explore a topic in depth where the intention is to understand and interpret a specific phenomenon, which is in line with the intentions of this research (Silkoset et al., 2021, p. 69). This research design was helpful as it is flexible and could be adapted to the changes that appeared during the research process.

In terms of the research approach, it is normal to distinguish between *deductive* and *inductive approaches*. These approaches show how data are organized and interpreted to achieve meaningful conclusions. The *deductive* approach is a form of reasoning that goes from existing theory to data by deducting from general principles to specific instances. The *Inductive* approach is a form of reasoning where one goes from data to theory by comparing multiple instances of a phenomenon to induce general principles (Easterby-Smith, 2021, pp. 266–267). As this research is based on existing theory, while at the same time it is dependent on the acquisition of new data the inductive approach was used.

4.2 Research Methods

4.2.1 Qualitative Comparative Case Study

When choosing a research method, the research literature distinguishes between two categories: *quantitative* and *qualitative* methods. While quantitative methods look to explain a phenomenon, qualitative methods look to go deep and explore a phenomenon. Quantitative data is data where the information is expressed in numbers or other units of quantity, while qualitative data is characterized as all other data (Silkoset et al., 2021, p. 117). This research

seeks to explore patterns related to the implementation of plastic waste management solutions and further understand and explore how these patterns can be used to create new viable and sustainable business models. This was performed through a qualitative research process as this was suited for the exploration of a phenomenon, in addition to coinciding with an explorative research design and inductive approach.

To acquire a sufficiently broad and deep, and detailed understanding of plastic recycling in rural Africa, this research project was conducted as a case study. Robert K. Yin (2018, p. 14) defines case studies as: *an empirical method that investigates a contemporary phenomenon in depth and within its real-world context, especially when the boundaries between the phenomenon and context may not be clearly evident.* Further, Yin suggests choosing a multiple-case design if you have the opportunity and resources to do so, as this can lower risks and result in more substantial analytic benefits (Yin, 2018, p. 68). Due to the explorative nature of my research question, my chosen methodology was to structure the research as a multiple-case design with the SUWASO project as the main case. Through this case, the aim was to identify different factors related to the territoriality, discourse, materiality, and organization dimensions introduced in Chapter 3.7. The findings from my main case were compared to data collected from two additional cases to increase the validity of this research. This provided multiple sources of data, strengthening the evidence for creating valid solutions.

4.2.2 Main Case and Supplementary Cases

This research was based on a main case and two supplementary cases. As I was personally engaged in the SUWASO project, I gained deep insight and knowledge about the project's development processes. It was therefore natural to structure this research based on my insight and findings from this project, making it my main case. I decided to use two supplementary cases to further inform and validate the findings from my main case. I chose to categorize these cases as supplementary, as I did not have the same engagement and insight compared to the SUWASO case.

The SUWASO case was selected based on an internship at Human Brights where I got introduced to the project. Details about the SUWASO project are described in Chapter 1.5. The supplementary cases were selected based on two criteria. Firstly, this research is a part of EWB's *Meaningful Master's Program*, and a sample criterion was that they had to be selected from the EWB project catalog. Secondly, the cases had to address plastic recycling in Africa. This led to the selection of the following projects: *Recycling station in Dar es Salaam* and *Green Jobs in Mali.*

4.2.3.1 Recycling station in Dar es Salaam, Tanzania

The first supplementary case is a project in Dar es Salam, Tanzania. The project took place in 2022 and was based on a request from NITO and designed by EWB in collaboration with a local project partner, Tanzania Explorer. The aim of this project was to support the UN's Sustainable Development Goals by installing a small plastic recycling facility based on an open-source system designed by Precious Plastics. The recycling station was set up near Mbongoland Beach in the northern part of Dar es Salaam where huge quantities of plastic waste get washed up on the daily tide. The idea behind the facility was to manage local challenges related to urbanization, leading to increased generation of plastic waste while waste management efficiency declines, and to a rising unemployment crisis among young people in Tanzania (Ingebo & Osborne, 2022).

4.2.3.2 Green Jobs in Mali

The second supplementary case is a project that is currently taking place in San and Bamako in Mali. The project was initiated by Strømme Foundation in 2019 and aims to establish two pilot factories in Bamako and San for recycling plastic waste into school benches. The purpose of the project is to create jobs and opportunities, especially targeted toward women and adolescents, while contributing to tackling the plastic waste problem in Mali. The project is divided into multiple phases, where phases 1 and 2 are completed, and phase 3 started in the autumn of 2021. The new recycling facilities are intended to be modeled after an existing facility in Burkina Faso and phase 1 of the project studied the existing production process and potential improvements. Phase 2 addressed improvements in areas of health, safety, and environment (HSE) and implementation of the 5S principles of lean production; sort, set in order, shine, standardize, and sustain. Work that will be done in Phase 3 includes refinement of production and HSEQ processes and design of technical solutions for the factory to test (Svendsen et al., 2019; Yasien Ahmed et al., 2022).

4.2.3 Multi-Method Research

While a mixed method combines both qualitative and quantitative methods, multi-method research is an approach that uses multiple methods from the same research tradition (Easterby-Smith, 2021, p. 134). This study used multiple qualitative methods when collecting data for the different cases, participant observation through fieldwork, document analysis, and qualitative interviews.

The methods when collecting data for the SUWASO case, consisted of participant observation during two field trips to Uganda and qualitative interviews. Participant observation can be

described as a mode where you are engaging in the actions that are being studied. This method can create distinctive opportunities for collecting data that would otherwise be inaccessible to a study. Additionally, this method allows the researcher to see reality from the perspective of someone inside a case rather than someone external, while also gaining the ability to manipulate minor events. However, one should be aware of challenges where potential bias can be produced. This can include scenarios where the researcher assumes a position or role that contradicts good social science practice, follows a phenomenon and become a supporter of the group being studied, does not have sufficient time to take notes or raise questions due to a high degree of participation, or if the researcher finds it difficult to be at the right place at the right time (Yin, 2018, pp. 123–125).

The first field trip took place from 31.03-08.04.2022, where the main objective was to gather information about the current state and practices in Uganda. Data collection from this field trip mainly consisted of qualitative interviews, which are discussed in further detail in Chapter 4.3.1. The second field trip took place from 16.04-29.04.2023, where the objective was to implement the project's technological solution together with a team of engineers from EWB. Data collection from this trip was heavily based on participant observation, where I took part in the development process and implementation of the technological solution together with both the project team and local actors. Data collection methods for the two supplementary cases consisted of qualitative interviews and document analysis. Document analysis is a method where documents are evaluated and interpreted to gain elicit meaning, gain understanding, and develop empirical knowledge (Bowen, 2009). For the two cases, I analyzed the project reports published by EWB, in addition to a feasibility study performed by the project in Mali, to gain insight and knowledge of the two cases. Additional data was collected through qualitative in-depth interviews, which are discussed in Chapter 4.3.1.

4.2.4 The Research Process

To simplify the research process, it was divided into four main phases, initial research, development of potential solutions, implementation, and comparative studies. The first three phases involved my participation in the SUWASO project. The first phase included desk research and initial fieldwork to create a fundamental understanding of the plastic problem in Africa and Mityana in particular. This fieldwork consisted of semi-structured interviews and observations. Findings from the initial fieldwork constituted the foundation for mapping existing structures, drivers, and challenges for the plastic waste management in Mityana. The second phase was to build on these data and develop potential solutions to manage the plastic

waste problem, including both technological and business-related solutions. The third phase included implementing these solutions through a second field trip to Mityana, where data was collected through participant observation. Lastly, data from the two supplementary cases were collected through desk research and interviews. The findings from both the main case and the supplementary cases were compared to each other and analyzed through the framework for plastic waste management innovation. The goal was to identify patterns and solutions that can be helpful for future projects.

4.3 Data Collection

When collecting data, it is normal to divide this by primary and secondary data. Primary data is defined as data collected for the purpose of a specific analysis, while secondary data is data that already exists, and that was collected for another purpose (Silkoset et al., 2021, p. 96). This research uses both primary and secondary data. In qualitative methods, primary data can be collected in multiple ways, for example, through communication with people, observations of people and through literature reviews (Silkoset et al., 2021, p. 117). The primary data collection in this research was collected through qualitative interviews, participant observations, and supplemented with qualitative secondary literature.

The primary data collection process was divided into three phases. The first phase consisted of the first field trip to Mityana, where the aim was to gain a deeper insight into the plastic waste problem and possibilities for setting up a recycling facility. The second collection phase consisted of qualitative interviews with project participants from the supplementary cases. Lastly, the third collection phase was the second field trip to Mityana, where the aim was to implement the project's technological solutions.

4.3.1 Interviews and Respondents

There are several forms of qualitative interviews when collecting primary data. This research utilized individual case study interviews and group interviews. Case study interviews can be defined as a guided conversation rather than structured queries. Case study interviews are likely to follow a line of inquiry reflected by a case study protocol while having a more conversational manner. These are called case study interviews as they explore aspects of a particular case but can also be referred to as in-depth interviews (Yin, 2018, pp. 118–119). One of the benefits of using in-depth interviews is that the information received may be more valid than information from group interviews. This is caused by a sense of trust and security as the respondent may feel more secure to share his or her true opinions without the fear of being judged by others.

There are also multiple benefits when using group interviews. Firstly, this interview method is more time effective compared to individual interviews. Secondly, this interview form can provide useful insight into how individuals or groups can react or perceive a certain issue (Easterby-Smith, 2021, p. 213).

In addition to participant observation, the data collection in this research consisted of individual interviews. This was mainly because I wanted to obtain a deep understanding of certain topics and to increase the validity of collected data. Group interviews were conducted when talking to several actors in the informal waste sector as this was more time effective, in addition to providing important information about the relationship between these actors. To avoid loss of data, the interviews were recorded and transcribed when possible. If recording was not possible, notes were taken during the interview process. This made it possible to note observations in body language, mood, and relevant surroundings. Most interviews were conducted in person, but three interviews were conducted digitally through Zoom and Teams as the respondents were in other cities. Video meetings were preferred over phone interviews as this allowed for a more personal connection and observation of body language.

When conducting the interviews, semi-structured interview guides were used, see Appendix C. The semi-structured interviews are beneficial as they cover several predetermined topics and questions, but in a flexible way that also opens for the introduction of new ideas and lines of questioning that may be relevant to the case (Easterby-Smith, 2021, p. 195). This kind of structure aids planning and asking questions that are important to collect relevant data, but also allows freedom in the way the interview is conducted. This means that the respondents may introduce a new topic that was not initially considered, but that may be relevant and valuable information to answer the research question (Easterby-Smith, 2021, p. 205). The initial interviews topics were based on a baseline survey performed by the local partner in Uganda, REDS. During the field trips to Uganda, it was not possible to provide the respondents with an interview guide before the interviews took place. However, all respondents were informed about the interviews and were given information about the SUWASO project. All respondents from the supplementary cases were sent a letter of consent before the interviews took place.

The respondents for the main case consisted of informal waste workers, potential business partners, plastic waste generators, radio channels, mechanical workshops, and representatives from the municipality. These respondents were selected by REDS as they already knew the relevant actors in the local plastic waste chain in Mityana. For the supplementary cases, respondents were selected based on their involvement in the two projects in Tanzania and Mali.

Engineers Without Borders provided contact information for participants in the two projects, and further respondents were chosen with the snowball method. A complete representation of the respondents is presented in Table 1.

Date	Interview object	Role	Interview form
01.04.22	Respondent A	Employee at a radio station in Mityana	Individual interview
01.04.22	Respondent B	Employee at a radio station in Mityana	Individual interview
01.04.22	Respondent C	Nun at a community center in Mityana	Individual interview
02.04.22	Respondent D	Plastic waste collector	Individual interview
02.04.22	Respondent E	Plastic waste collector	Individual interview
02.04.22	Respondent F	Plastic waste collector	Individual interview
02.04.22	Respondent G	Plastic waste collector	Individual interview
02.04.22	Respondent H	Plastic waste collector	Individual interview
02.04.22	Respondent I	Plastic waste collector	Individual interview
02.04.22	Respondent Group J	Leaders in local plastic waste cooperation	Group interview
04.04.22	Respondent K	Chief at local market	Individual interview
04.04.22	Respondent L	Vendor at local market	Individual interview
04.04.22	Respondent M	Deputy headteacher at local school	Individual interview
05.04.22	Respondent N	Representative from Mityana Municipality	Individual interview
06.04.22	Respondent O	Representative from Coca Cola	Individual interview
06.04.22	Respondent P	Owner of local mechanical workshop	Individual interview
07.04.22	Respondent Q	Representative from Quality Plastics Limited	Individual interview
03.04.23	Respondent R	EWB engineer – Recycling station in Dar es Salaam	Individual digital interview
03.04.23	Respondent S	EWB engineer – Recycling station in Dar es Salaam	Individual interview
04.04.23	Respondent T	EWB engineer – Green jobs in Mali	Individual digital interview
09.05.23	Respondent U	Project owner, Strømmestiftelsen. Green Jobs in Mali	Individual digital interview

Table 1 – List of Respondents

4.3.2 Fieldnotes

All data that was collected through interviews and participant observations during the field trips to Uganda were kept in two separate field diaries, one for 2022 and one for 2023. During the interviews I took notes as it was not suitable to record the interviews due to background noise or other circumstances. As an alternative, I listened closely to what was being said during the

interviews and noted down as much as possible in a notebook. Multiple persons from the Norwegian project team participated in the same interviews and took additional notes. The notes from the interviews were later written into an electronic field diary, where I supplied any missing information with the notes from the other project members. All interviews were marked with dates, locations, and attendees. At the end of each day during the fieldwork we had a short briefing on the performed work. Any additional data from observations or discussions were kept in the diaries.

During the second field trip, most data was collected through participant observation. To avoid a loss of data, multiple pictures were taken during the modification and implementation process of the technological solutions. Each day I kept notes of all the tasks that had been performed, any challenges met, and how these were solved. All data and information that appeared from discussions and conversations with different actors during the field trip were also kept in the diary. All notes were marked with dates, locations, attendees, and other remarks I saw beneficial. Additionally, both field diaries contain project information collected through external and internal meetings, emails, and other relevant discussions both before and after the field trips were conducted. The total data collected from 2022 were kept in the field diary for 2022, while data collected in 2023 was kept in the second field diary from 2023.

4.3.3 Desk Research and Secondary Data Sources

In addition to primary data collected from interviews and observations, various sources of secondary data were used. Secondary data is divided into *internal data,* which is information sources already within an organization, and *external data*, which is sources of information that are not under the organization's control. The external secondary data sources can be divided between Big Data, public sources, non-fiction literature, and standardized surveys (Silkoset et al., 2021, pp. 97–98). To gain initial knowledge about the state of plastic waste management in rural Africa, an important phase of this research was to explore already available information. During the desk research phase, mostly external secondary data was used. The external secondary data sources consisted of research related to various aspects of plastic waste management, challenges, and potential solutions in rural Africa, in addition to project reports from "Green jobs in Mali" and "Recycling station in Dar es Salaam". During the research process I was also presented with internal secondary data. These data consisted of internal reports, including an initial baseline study and waste audit performed by REDS, and a feasibility study performed by partners of Strømme Foundation.

When using secondary data, it is important to be aware of potential sources of error. Some examples of sources of error are *selection errors*, which may occur when examining a selection instead of a whole population, *non-selection errors*, which refer to respondents being inaccessible, used twice or if the questions asked are leading or unprecise (Silkoset et al., 2021, p. 104). Other errors can be related to errors in interpreting the data, bias, or data manipulation.

To avoid selection errors, multiple research sources were used in the research process. There were some limitations on available data regarding plastic waste management in a rural and local context, such as specific amounts of plastic waste generated and managed in Mityana. This might have resulted in some degree of selection errors as the full population was not represented due to a lack of data. However, since the secondary data sources were used to supplement my findings from the primary data collection, I considered the risk of selection errors to be low. To avoid non-selection errors all sources were critically evaluated through assessment of their methodology, validity, and reliability. Other errors were avoided by staying objective when interpreting data, in addition to searching for multiple sources within comparable topics. For the supplementary cases I did not consider the project reports as a sufficient source of data, and additional primary data collection was performed through interviews.

4.3.4 Validity

When conducting research, it is important to assess how well data collection is performed by looking at validity and reliability. Validity addresses how well the data measures what it was intended to measure (Silkoset et al., 2021, p. 88). There are multiple tests that can be performed to check the validity of data, assessing the construct, internal- and external validity. The *construct validity* identifies the correct operative measures for the concepts that are being studied, and a tactic is to use multiple sources of evidence and to have key informants review the draft of the case study report. The *internal validity* assesses the relationship between the measured conditions so that certain variables' impact on the results can be excluded. This can be done by doing pattern matching, using logic models, and addressing rival explanations. The *external validity* shows how a case study's findings can be generalized and can be done by using replication logic (Yin, 2018, pp. 42–46).

To increase the construct validity, I ensured that information was collected from multiple sources, and therefore was more likely to be valid. This was done by interviewing different stakeholder groups with multiple respondents in each group. A semi-structured interview guide was made to make sure that the questions asked, and information received matched the research objectives.

The main concern for this research was related to internal validity due to my personal engagement in the SUWASO project. As I have followed this project closely and participated in the development and implementation process of both the technological solution and business model, I may have been unaware of potential bias produced. However, as I wanted all projects to be successful to tackle plastic waste pollution in rural Africa, I tried to stay objective to find factors that can contribute to developing successful projects in the future. To increase the internal validity, all projects were treated equally by analyzing them through the same analytical framework. Key findings from the main case were compared with other cases using the pattern matching tactic. Still, since I had more insight into the SUWASO project compared to the other cases, some bias may have been produced. Lastly, it is important to note that the interviews with respondents R, T and U were conducted in Norwegian. These interviews were not translated when analyzed, but quotes presented from these respondents were translated into English. During the translation process care was taken not to alter the true meaning of the quotes.

Regarding external validity, the findings from this research contributed to an increased insight into building profitable business models around plastic waste in rural areas. The findings and analytical framework from this research can be generalized and used in other projects and countries with a rural or semi-urban context, increasing the external validity.

4.3.5 Reliability

The reliability of a research study assesses the stability of collected data. This is done by measuring if results vary when the same data collection procedure is performed multiple times. If the result varies, the data is less reliable and if the results are consistent, the data is more reliable (Silkoset et al., 2021, p. 154). However, case studies are normally not repeated as the opportunity to do so rarely occurs. To ensure reliability it is therefore important to document the procedures of a case study, so that the research can be replicated in theory. This can be done by using various tactics such as a case study protocol and developing a case study database (Yin, 2018, pp. 43, 46). A case study protocol should consist of four different sections: an overview of the case study, data collection procedures, protocol questions, and a tentative outline for the case study report (Yin, 2018, p. 94). The case study database is a way of organizing and documenting all the collected data and should include both primary and secondary data sources (Yin, 2018, p. 131).

To support a prominent level of reliability I have chosen to keep a chain of evidence throughout the research process. This involved using both a simplified case study protocol and creating a

case study database. The case study protocol was used as a template for data collection for all three cases to ensure that data collection and analysis were treated equally. All primary data sources were documented, labeled, and saved digitally. Both primary and secondary data sources were uploaded to the research software *Zotero*. This made it easy to keep a chain of evidence as all findings could easily be traced to the case study database, which again could be traced to the case study protocol and research questions.

4.4 Data Analysis

Analyzing collected data can be a complex process that stagnates the research process, but there are several strategies and techniques that can be used to aid the process. One of these strategies is to rely on the theoretical propositions that led to the case study (Yin, 2018, pp. 165, 168). To interpret and analyze the collected data, an analytical framework was developed based on the theoretical propositions and existing research that appeared in my literature review. This framework was presented in Chapter 3.7 and consisted of four main dimensions: territoriality, discourse, materiality, and organization. The idea behind this framework was to create a model that made it easier to recognize similarities and differences between the three cases, using pattern making as an analytical technique. One of the most desirable techniques is to use a pattern-making logic that compares an empirically based pattern with a predicted pattern that was made before data was collected. This way, the predicted patterns may be confirmed or create the need to dive deeper to find alternative explanations (Yin, 2018, pp. 175–177).

All data collected were organized into four categories that matched my analytical framework, looking for patterns within each category. The first category, *territoriality,* included information related to the composition of plastic waste, how plastic waste was managed, mapping of different actors within the plastic waste management sector, challenges experienced by these actors, and other relevant market research. The next category, *discourse,* included information about the project's main goals, incentives, and ethical considerations. The third category, *materiality,* included access to resources and equipment, technology development and implementation, and challenges experienced by the project. The fourth category was *organization,* which included possibilities to build on existing value chains, developing business models, and project results after the implementation of solutions. These categories were beneficial when interpreting and analyzing my data through my chosen analytical framework and made it easier to detect patterns from the various cases.

4.5 Limitations

There were a few limitations to this study that needed to be addressed. Firstly, the data collected needed to be critically evaluated to reduce the risk of producing biased information. Interviews were mainly conducted physically to avoid loss of important information. All respondents were critically assessed as the information provided could be inaccurate or deficient. To avoid unclarity or leading the respondents' answers, the interview questions were open and clearly formulated. This was especially important since some interviews were international, and it was important to avoid language barriers or confusion. It was also important to create a good relationship with the respondents so that they could feel confident in sharing information. This was done by being friendly, telling any intentions with a meeting or interview, making sure to keep any promises that were made, and bringing local actors that gave the project credibility.

A second limitation of this research was the timeframe. Data collection was already a time-consuming process, but due to an Ebola outbreak in Uganda, the planned fieldwork was postponed from January 2023 to April 2023. As this research had a deadline in May 2023, I was not able to collect any long-term results from the SUWASO case after implementation. This limited the research to short term results, and further research is needed to assess any long-term effects on the implemented solutions of the SUWASO project. Lastly, this research was limited to findings that appeared from the chosen theoretical framework and cases. It is therefore likely that several factors of importance, such as circular economy principles, were not considered in this research.

4.6 Ethical Considerations

During a research process, there are multiple ethical issues that might occur and must be managed. To ensure an ethical practice I decided to follow Easterby-Smith's (2021, p. 173) 10 key principles in research ethics: Ensuring that no harm comes to participants, respecting the dignity of research participants, ensuring a fully informed consent of research participants, protecting the privacy of research participants, ensuring the confidentiality of research data, protecting the anonymity of individuals or organizations, avoiding deception about the nature or aims of the research, declaring affiliations, funding sources and conflicts of interest, communicating research honestly and transparently, and avoiding misleading or false reporting of research findings.

First, the project included talking to multiple different participants, and it was important to protect and handle the participants with integrity. The research project was reported to NSD

and was managed according to their guidelines. All participants were anonymized, and data collection and data storage followed GDPR guidelines. Further, all participation in this research was voluntary, and participants could choose to withdraw from the research at any time. During the interview process, participants were informed about my research project and the purpose of the interview, either orally or through a letter of consent. It was important to create a good relationship with the participants based on trust and honesty, as this not only maintained their wellbeing, but also helped to validate and obtain valuable and trustworthy data. Secondly, as this research included multiple field trips to a new country with new cultures, it was important for me personally and for the project to act in a respectful and safe way. To ensure safe practices I followed EWB's guidelines for fieldwork in addition to performing a personal Safety and Security course from Disaster Ready. To avoid issues regarding corruption, I followed EWB and NGI's respective anti-corruption policies.

Further, it was important to ensure that the research project did not cause any negative impacts on the participants or the local community in Mityana. The SUWASO project aims to support and strengthen the local community by improving structures for plastic waste management, and therefore increasing the income basis for people in the industry. While doing this it was important to ensure that the activities of the SUWASO project did not harm or remove the livelihood of other actors in the local community. It was therefore essential to choose good analytical tools and consider all potential outcomes from our actions before implementing them. To reduce the risk of negative impacts, the Triple Layer Business Model Canvas was used as an analytical tool. Lastly, I was working closely with REDS, the local partner in Uganda, and the Mityana municipality to ensure that all work performed was in line with local guidelines.

5.0 Discussion

This research aims to answer the following research question *"How can business model innovation and technology adaptation increase the viability of plastic waste recycling in the informal waste sector in rural Africa?".* In this section I seek to analyze the three projects in Uganda, Tanzania, and Mali through my framework for plastic waste management innovation. The aim is to discuss whether the different projects can be characterized as responsible innovation projects over the four dimensions, territoriality, discourse and ideation, materiality, and organization. The findings through this discussion will reveal how the various projects have managed innovation related to technology adaptation and business model development, and how this affects plastic waste recycling. Finally, I discuss how future innovation projects can

manage innovation to adapt technology to local conditions and develop more sustainable and viable business models in the future.

5.1 Territoriality of Plastic Waste in Rural Africa

This chapter looks at the three project's territoriality, which is the first dimension of my analytical framework for plastic waste management innovation. The territoriality concerns the local context where the projects will operate, as well as the project's contextual knowledge. The key elements discussed in this section are the current state of plastic pollution, current waste management practices, and drivers and challenges related to plastic waste management. Lastly, I discuss the importance of preliminary work when mapping the territoriality, in addition to how this affects further development of the plastic recycling projects.

5.1.1 Current Waste Situation and Practices of Plastic Waste Management

5.1.1.1 Mityana, Uganda

The territoriality in Mityana, Uganda, was assessed through a baseline survey performed by the SUWASO project's local partner REDS and a field trip to Mityana during the spring of 2022; see Appendix D for additional details. This assessment revealed that Mityana municipality has a population of around 100.000 people, consisting of approximately 24.042 households. Plastic waste is a significant problem in the municipality where around 15 tons of garbage, including plastics, are generated daily. The waste management composition and fractions are unknown by the municipality, but based on Hoornweg and Bhada-Tata's (2012) statistics, it can be estimated that around 1950kg of plastics is generated every day. The most generated plastic types by households were Polyethylene bags (LDPE) and plastic bottles (PET), while other types of plastic waste consisted of broken jerry cans, basins, buckets, plastic containers, and utensils, which are generally made of High-density Polyethylene (HDPE). 60% of local revenue that is collected monthly by the municipality is used for garbage collection and transportation to the landfill. This revenue is originally earmarked for other activities (REDS, 2021).

The collected waste is transported to a landfill in Namukozi in the Central Division. However, this landfill is almost full of non-biodegradable waste, primarily plastics and rubber. As a result, the municipality needs an additional landfill which can contribute to lowering transportation costs. A lot of the waste does not reach the landfill, and plastic waste was littered in the streets,

and unofficial dump sites with large accumulations of plastics can be found throughout the town (Langseth, 2022). The general awareness of plastic waste management in the municipality is low, leading multiple households to utilize plastic waste for cooking, causing hazardous emissions (REDS, 2021).

The current waste management practices in the municipality are poor, and sorting waste is not a common practice. The municipality has a limited capacity for garbage collection as they only have one truck, and it is unable to cover the whole municipal area daily. The collection rates therefore vary from 2-3 days a week to once every two weeks. Some areas are not covered by municipal garbage collection, and alternative practices have emerged such as openly burning plastics. However, in addition to municipal garbage collection, the informal sector has become an important role. This sector mainly consists of plastic waste business collectors (PWBC), that collect and buy waste from households and resell it to intermediaries (Langseth, 2022; REDS, 2021)

5.1.1.2 Dar es Salaam, Tanzania

Due to a lack of time the project in Tanzania did not have time to do preliminary research but used secondary data sources to map the project's territoriality. Dar es Salaam is the capital of Tanzania with around 7.000.000 inhabitants. The plastic waste generation was estimated to be 700 tons in 2017, but this is a growing trend due to urbanization. The city is struggling with a scarcity of funds, causing a decline in waste management effectiveness and over 40% of the waste in Tanzania enters the environment. In 2014, around 22% of the total waste composition was plastics, where PET was identified to be one of the main pollutants (Ingebo & Osborne, 2022). There has also been an effort to fight the rise of plastic pollution by banning polyethylene bags (LDPE), and respondent R informed that the ban has been effective: "*It is actually illegal to bring plastic bags to Tanzania and you don't get them in stores and such, so this has made a huge difference when it comes to plastic bags at least*" (Respondent R, 03.04.2023). See Appendix E for additional details about the territoriality in Tanzania.

Due to the lack of time to do preliminary research the project was not able to map the current waste management practices in Tanzania, but they knew that recycling efforts have increased in the last years, and private investors are targeting HDPE, PVC, and PET plastics. There has also been formed an association that promotes the growth of plastic recycling and the use of eco-friendly packaging and bags (Ingebo & Osborne, 2022). Respondent R further informed that there was a system for collecting and recycling transparent plastic bottles:

"*They have managed to create some sort of system for collecting transparent water bottles. They collect transparent PET and get some money per kilo, but I do now know the amount. I do not remember the exact business model, but the transparent PET bottles are much easier to recycle and there are facilities that manage it"* (Respondent R, 03.04.2023).

5.1.1.3 Bamako and San, Mali

During an interview with the project owner, respondent U, it was informed that the project's territoriality was mapped through a feasibility study. The feasibility study was performed by local consultants that assessed current and expected waste volumes in Bamako and San, and potential production opportunities (Respondent U, 09.05.2023). The study revealed that Bamako had around 2.525.931 inhabitants in 2018, but is facing significant migration flows, especially among young people. A rapid urbanization rate of 25% poses a challenge to providing people with acceptable urban services. The city of San had a population of 79.576 in 2018, where 31,35% consisted of people with no level of education. The context in San is semi-rural where more than 32% of the population are devoted to agricultural practice. Both cities generate high quantities of waste, where Bamako produces 645.000 tons yearly, and San generates 14.6000 tons yearly. Of these quantities, 45.000 tons in Bamako and 1022 tons in San are estimated to be plastics. The main plastics encountered in Bamako and San are PET, LPDE, HDPE, and PP. However, plastic bags (LDPE) are especially mentioned as an issue as they are spread in both rural and urban areas, causing environmental impact (Zoure & Nonguierma, 2019).

Waste management in Mali is a serious challenge and Bamako faces health issues due to poor waste collection systems, insufficient infrastructure, and difficulties in evacuating waste from transit points. The municipality is also facing financial issues, where the municipal budget rarely dedicates capital to waste management. In San, the waste management system is almost non-existent, leading to unofficial dumpsites and high levels of plastic waste. Due to the current state the cities are facing negative externalities, including degrading of aesthetics and living environments caused by plastic pollution, toxic emissions due to incineration, and impacts on wildlife and agriculture (Zoure & Nonguierma, 2019).

The waste management sector in Mali consists of informal collectors, intermediaries such as wholesalers, and processors. There is a presence of plastic waste processing industries, and existing local, national, and international markets for products derived from plastic waste. Harder plastics are generally used for material valorization by making resins, while lighter

plastics are used for production of paving stones. Further, reuse of plastic bottles is highly developed. Lastly, there were established existing structures of an expansive and experienced informal sector that mainly are made up of women and young people (Zoure & Nonguierma, 2019).

In Bamako, the municipality is responsible for the transportation and treatment of waste. However, most activities are performed by informal and private actors. The municipality has contracts with what the study refers to as economic interest groups (GIE) in the informal sector. Plastic waste is collected by informal workers daily, mostly by out-of-school children, women, and rag pickers. The intermediaries, usually young people from villages, are the first buyers that often walk or ride bicycles to find goods to buy. Resale of the collected plastics is usually at the wholesale level, which sells to factories or exporters. Even with daily plastic waste collection by the informal sector, the collection rate in Bamako is highly irregular, and was estimated to be around 54% in 2010. Burning is still the most used waste management practice throughout the city (Zoure & Nonguierma, 2019).

In San the situation is very poor and there are no dedicated collection points or landfills, causing waste to be stored in plain sight. The municipality is aware of the accumulation of unofficial dump sites, and sometimes organizes waste removal from these sites. Like in Bamako, burning is a commonly used waste management practice. There are also some GIEs involved in the waste collection (Zoure & Nonguierma, 2019). See Appendix F for additional information on the territoriality in Mali.

5.1.2 Gain of Contextual Knowledge

5.1.2.1 Mityana, Uganda

When mapping the territoriality, the project gained contextual knowledge that became important for the development of the technological solutions and business model. The project interacted with multiple PWBCs and learned that around 20 collectors had their own stores for different kinds of scrap, mainly metal and plastics. Several of the PWBCs in Mityana have come together to form a cooperative with a main goal of increasing working capital and efficiency. This cooperative was registered in October 2020 and consisted of around 150 PWBCs (Langseth, 2022; REDS, 2021). It was further informed that the PWBCs employ workers that drive around on motorcycles or bicycles to collect plastic waste from households. The average load per motorcycle depends on what kinds of plastics are collected, but Respondent D estimates around 60kgs per run (Respondent D, 02.04.2022). It was further

discovered that HDPE and PP were the most collected plastics due to higher margins. PET was normally not collected as the prices were low, making it unprofitable. Each worker is provided with capital to buy plastics, before it gets transported back to the plastic waste business collectors, weighed, and sorted. The plastics are then sold to recyclers in neighboring districts and Kampala. Some PWBCs manually cut the plastics into smaller pieces to increase the plastic load per truck. The average load per truck was around 4 tons of plastics (Langseth, 2022). See Appendix D for additional details, and experienced prices and costs.

It was also discovered that both the PWBCs and recyclers struggled with price fluctuations. Other challenges experienced by the PWBCs were high transportation costs and lack of capital. This led to lower margins, as they weren't always able to fill a whole truck with plastics (Respondent D, E, and G, 02.04.2022). These collective challenges were one of the main incentives for founding the plastic cooperative. The current leaders of the cooperative, Respondent Group J, informed that the first idea behind the cooperative was to increase production capacity and to lower transportation costs through collaboration. Other goals behind the cooperation are to achieve a cleaner environment, especially by removing bottles from drainage canals (Respondent Group J, 02.04.2022). Respondent D also informed that the municipality potentially would provide funding to the cooperative, around 30.000.000 UGX, if they can get 300-400 members to join the cooperative (Respondent D, 02.04.2022). These economic drivers have seemed to be effective as many of the PWBC were positive towards joining the cooperative. However, getting enough PWBCs to join the cooperative has been a challenge, and Respondent D claims that not all are interested in collaborating (Respondent D, 02.04.2022).

The municipality was also generally positive towards the SUWASO project and was happy that the project had multiple positive interactions with the various actors in the local community. Respondent N shared a vision of Mityana being a great center for plastic recycling that could inspire surrounding communities. Other desirable outcomes were also mentioned, such as reducing the trash that ends up on the landfill, and potentially reducing plastics that reach Lake Wamala. Lastly, respondent N also mentioned that a fraction of the facility income might be claimed by the municipality, but it was unclear in what way (Respondent N, 05.04.2022). This could indicate that the municipality has economic incentives when including non-governmental organizations (NGOs) in plastic waste management.

Lastly, related to the lack of awareness around plastic waste management, the project talked to two radio stations in Mityana. Respondent A, a radio host at the first radio station claimed that

there is a somewhat troubled relationship between citizens and the municipality. This was explained by the municipality forcing citizens to do more environmentally friendly activities which leads to increased costs (Respondent A, 01.04.2022). Both radio stations seemed positive toward spreading awareness and suggested performing talk shows to educate citizens about plastic waste pollution and plastic waste management (Langseth, 2022). Respondent B, a radio host at the second radio station suggested that in addition to talk shows, adverts would be an effective way to reach out to the people in the municipality. It was also suggested to air the talk shows during their prime time, which is between 17:00 and 20:00 (Respondent B, 01.04.2022).

5.1.2.2 Dar es Salaam, Tanzania

As the project did not have the opportunity to research the local conditions, there was also a reduced gain of contextual knowledge. However, respondent R informed that there was a lack of infrastructure related to waste management: "*There are people that collect plastic waste, but there is very little infrastructure. There is no one that is assigned to collect it…which is why we have beach cleanings"* (Respondent R, 03.04.2023). During the implementation phase of the technological solution, respondent S informed that they were able to talk to some of the waste pickers that were collecting transparent PET-bottles, which revealed that there is a market for PET-bottles:

> "*We also talked to some of the pickers of clear plastic waste. They gave us a price for what they sold it for, but I can remember the number. I know they sell it to Chinese recyclers… It seemed like they had a truck coming in every week"* (Respondent S, 03.04.2023).

It was discovered that multiple businesses and actors were engaged in reducing waste management problems. The Tanzania Recyclers Association promotes the growth of the plastic waste industry. Additionally, interviews with the project participants in Tanzania revealed two businesses that decided to act, Nipe Fagio and Tanzania Explorer (Respondent R and S, 03.04.2023). In 2018, Nipe Fagio organized 26 clean-up campaigns, which yielded an impressive 16,500 kilograms of waste (Ingebo & Osborne, 2022). According to interviews with respondents S and R, Tanzania Explorer was the business that started the project after seeing a significant amount of plastic waste on the beach. The company also looked to develop a viable business model for plastic recycling (Respondent R, 03.04.2023).

> *"It is Tanzania Explorer, this safari business, that has a Villa near the beaches that sees that this [plastics] are a big problem, so their incentive is to find business models that*

make it viable to do plastic recycling. The founder of Tanzania Explorer seems like an idealist and wants to create, well, I think his driver and goal is to create some sort of awareness around plastic recycling" (Respondent R, 03.04.2023)

Lastly, Respondent S noticed that many people were not familiar with recycling but that they got interested when they heard that there were business opportunities. Most people were very enthusiastic and positive towards talking about plastic recycling, but respondent S also experienced friction with some informal waste collectors: "*No, I just remember it was quite difficult to talk to them [waste collectors]. There was kind of a skepticism. It was, it was not an easy conversation to talk with them. I'm not sure why"* (Respondent S, 03.04.2023).

5.1.2.3 Bamako and San, Mali

During mapping the project's territoriality, the project gained valuable contextual knowledge. It was established that there was a market for plastic waste, which is valuable insight when developing business models. One important factor was that even if there were an existing structure of informal plastic collectors, intermediaries, and processors, the general network and collaboration between these actors were poorly organized. Each actor usually works their own way to maximize profits. Additionally, the existing structures in the informal waste sector were expansive and experienced, and mainly consisted of young people and women. Conversations with Active Speed Schooling Strategy (S3A) and Saving for Change (SFC) revealed that they are willing to work in the waste collection sector and give support through training and advisory support. Additionally, women from the SFC group in San showed interest in the project's recycling unit. They proposed that they could ensure purchase and collection of plastic waste, and resell this to the unit (Zoure & Nonguierma, 2019).

The feasibility study included a market analysis where it was revealed that there was a table-bench deficit of 48.274 in the Bamako district, and an additional estimated need of 24.859 table benches in the district of San (Zoure & Nonguierma, 2019). Respondent U also informed that Strømme Foundation has its own educational institutions in Mali where they have a need for school desks. From his experience there has always been a deficit of benches as they break and need replacement. Additionally, traditional school desks are made of wood, which is a scarce resource in Mali (Respondent U, 09.05.2023). The project has access to raw materials through a women's cooperative that collects, washes, and sells LDPE bags, which can be used to produce school desks (Respondent T, 04.04.2023).

In Bamako there are 180 active GIEs in the waste management sector, but they are facing multiple challenges that make their actions ineffective. They have a low level of equipment, and the payment rates for waste collection fees by households are low. Additionally, the waste recovery and treatment sector are unstructured and there is a lack of coordination between actors. The GIEs are also facing challenges with the absence of a Technical Landfill Centre, and insufficient transit depots as only three are currently functional. Lastly, they are experiencing a low awareness among citizens for a positive change in public and domestic hygiene behavior (Zoure & Nonguierma, 2019). There are also indications that the general awareness of plastic waste management is low, and Respondent T experienced emergence of acute dumpsites where people would drop their waste (Respondent T, 04.04.2023)

There are some governmental actors that support the town halls with the sanitation work in Bamako. There is a supervising ministry through the *National Directorate of Sanitation, Pollution and Nuisance Control*, that provides transportation equipment such as tractors, buckets, and tricycles. The local consultant conducting the feasibility study interviewed the municipal authorities, revealing a struggle to manage the waste that was transferred to them. Additionally, due to political reasons, some temporary deposits in Bamako have been closed for some time. This has caused the creation of massive wild deposits throughout the city. There are some valorization actions taken by the city to encourage waste collection, but these have not been sufficient to have a serious impact on reducing the quantity of waste (Zoure & Nonguierma, 2019)

Lastly, the project met some cultural differences that need to be considered. Respondent T informed that there were challenges related to one of the facilities in Mali, as it was not connected to a power grid. Due to the facility's location and high costs, it was not feasible to install electricity. As a solution, it was discussed to set up some machinery driven by a bicycle, but this was not accepted by the local workers; "*That was not something to be done there. It was ok to do the work by hand, but cycling? That wasn't something that one should do there"* (Respondent T, 04.04.2023). This indicates that it could be a challenge to find both efficient and the right equipment for processing plastic waste.

5.1.3 Territoriality Discussion

Based on the three different cases it seems like PET and LDPE are the primary sources of plastic waste pollution. Together with insufficient knowledge and awareness of plastic waste recycling, these materials often end up polluting nature. Further, for each individual case, it seemed like there was an existing market and value chain for plastic recycling, with the informal sector

playing a significant role. Informal waste collectors gather plastics from nature and households, and sell them to intermediaries, who then sell their products to larger businesses.

Findings from the projects' territoriality suggest that economic incentives are one of the main drivers for plastic waste recycling in the informal sector. This can be explained by the job opportunities created by informal waste services, therefore providing a source of income for informal waste workers. Findings from the project in Uganda revealed that PET bottles were not collected due to low profit margins, which supports economic incentives as a driver. Additionally, the project in Mali showed that the municipality tried to create economic incentives by taking measures to increase the valorization of plastics. These measurements also can also indicate that a cleaner environment by reducing plastic pollution could be a driver. This can be supported by findings from the project in Uganda and Tanzania. The municipality in Mityana shared a vision of becoming a center for plastic waste recycling that could inspire nearby communities, while Tanzania implemented a ban on plastic bags to reduce plastic pollution. Additionally, there have been calls in Tanzania to introduce stricter controls and legislation towards manufacturers to come up with solutions for how their products can be recycled (Ingebo & Osborne, 2022).

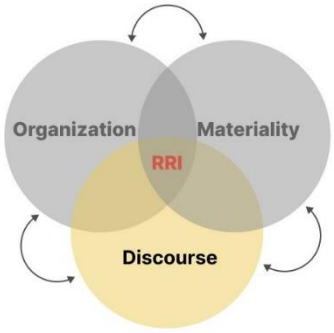
The most common challenges seemed to be related to low profit margins, poor access to capital, and poor quality of equipment, and a lack of access to equipment. The municipalities in all three projects experienced challenges with sufficient capital. In Mityana the municipality must use funds earmarked for other activities for waste management, but the services provided are still insufficient to tackle the plastic pollution. Similarities were found in Tanzania which struggles with scarcity of funds, and Mali which rarely can dedicate capital to waste management services. Findings from the project in Uganda showed that the PWBCs are struggling with price fluctuations, low margins, and poor access to capital. The GIEs from the project in Mali shared similar challenges with low profits, poor quality of equipment, in addition to poor coordination between actors.

It was clear that the three cases had various degrees of preliminary work. The project in Uganda had a high degree of preliminary work, including both a baseline study, individual interviews, and observations through fieldwork. This can significantly contribute to a more profound understanding of the project's territoriality. In contrast, the project in Tanzania did not have the opportunity to conduct surveys or interviews and relied on desk research to gain an understanding of the current situation. The project in Mali had a high degree of preliminary work. However, the interviews conducted during the feasibility study were mainly with

government structures, municipalities, NGOs, entrepreneurs, and partners of the Strømme Foundation (Zoure & Nonguierma, 2019). For the project in both Tanzania and Mali it could be beneficial to dive deeper into the informal sector to further map the perspectives, drivers, and challenges experienced by the informal waste workers.

One could argue that the level of preliminary work can greatly impact the results from projects in the three cases. Preliminary work is important to understand the territoriality of a project, and therefore gaining contextual knowledge which is an important factor in innovation processes. This can be linked to the empathy phase of the design thinking process, see Appendix G. This phase is essential in developing a deep understanding of a particular problem and finding its root cause. Without this understanding, it can be challenging to come up with potential solutions to solve local problems. This does not necessarily mean that it is impossible to develop good solutions. However, they might be less nuanced due to a lack of knowledge. It is still important to acknowledge that different projects will have varying opportunities and capabilities to conduct preliminary research based on their available resources.

5.2 Discourse and Ideation



This chapter discusses the next dimension of my analytical framework, which is discourse, and ideation. This dimension concerns the knowledge behind the project and how this is used in decision-making when assessing and developing solutions. In this section, I will assess the intentions behind each project and whether these align with the aspects of the TBL, which is the criteria for being considered a responsible project seen through the discourse dimension. Further, I discuss how these intentions, combined with insight from the territoriality dimension, can be used as a tool to achieve a responsible innovation project and desired outcomes.

5.2.1 Mityana, Uganda

As introduced in Chapter 1.5, the SUWASO project aims to create a complete waste management solution for three main waste sectors: plastic, organic, and residual waste. This research only covers the subproject of plastic waste which addresses rural and semi-urban scenarios. The project's main narrative is based on four main criteria for developing the complete waste management solutions. Firstly, the project is intended to be based on a strong local context, where collaboration is a key factor in all steps of the process. Secondly, it is important that the designed solutions work in harmony with current practices. Thirdly,

sustainability is a core aspect and long-term solutions are essential. Lastly, the project should combine a strong technical team and a locally based partner organization with broad experience in project implementation. The plastic subproject then has three main goals: collecting and sorting plastics, processing plastics into products with a market value, and using technology that is suitable for the local environment (NGI, 2021).

Based on the project intentions, the project used its contextual knowledge to discuss potential solutions for technology and business model development. One of the key learnings was that the PWBCs in Mityana wanted to create a business with the plastics they already had on hand (Langseth, 2022). To do so, Respondent Group J informed that they would like to have a shredder, washer, dryer, and extruder to create plastic pellets. They believed that if they had proper tools, they could increase the transport of plastic waste from 2 to 10 tons (Respondent Group J, 02.04.2022). Another important takeaway from the field trip was that the PWBCs already had experience with using both locally produced and imported machinery for plastic waste management. This concluded two key issues. First, there had been a locally produced diesel-run shredder in Katue, but this was of inadequate quality and broke down quickly. Further, the motor was not strong enough to shred harder plastics and the broken machine was sold to a competitor. Secondly, other machines are often imported from China. In this case the machines are ordered from abroad and locally assembled by a company representative. However, issues arise if the machine breaks as there is a lack of local competence and knowledge to maintain and repair the machinery (Langseth, 2022).

This knowledge created the criteria for designing long-term solutions that were suitable for the local environment. The technological solutions should be developed with a focus on easy maintenance and low complexity, based on utilizing locally available resources. By sourcing and building the machines in Uganda the project could contribute to building local knowledge and competence. Taking this approach can support the long-term use of the machinery as both competence and spare parts are available for maintenance and repairs (Langseth, 2022, 2023). The input from stakeholders, in this case PWBCs, can be seen as third-degree citizen involvement according to Voorberg et al. (2015) three categories of co-creation. Additionally, a local school in Kampala was involved in the production process, which supports the project criteria of collaboration in all steps throughout the process. The development process of technological solutions is discussed in greater detail in the materiality dimension in Chapter 5.3.1.

The market potential for recycled plastics was explored by talking to other stakeholders such as recyclers. This showed that there is a market for shredded plastics as there is an increased demand for using recycled plastics in products such as PET-bottles. This led the project to explore potential business models for shredded plastics rather than recycling the plastics into a finished product with market value. Further, a key criterion for developing a sustainable business model is to strengthen the local market structures, and to avoid restricting the livelihood of already vulnerable groups, such as plastic waste collectors (Langseth, 2022). Business model generation and organizing for sustainable plastic waste management are discussed further in Chapter 5.4.1.

The project also interacts with the municipality to ensure a good relationship between the project and its stakeholders. The municipality is updated on the project's progress through meetings, and official representatives have also been involved in data collection (Langseth, 2022). A desired outcome of involving the municipality is to gain positive effects such as embracement of citizen engagement, and to build trust and satisfaction between citizens, actors in the plastic waste sector, and the municipality (Brandsen et al., 2018). In July 2022 there was a launch of the SUWASO project that was held at the Mityana Municipality Landfill. During the event the SUWASO project provided a total of 18 landfill workers with protective wear. The mayor encouraged the workers to use this to protect themselves from toxins and diseases. Multiple municipal officials were also present and interacted with the landfill workers and appreciated their work and contribution to reducing plastic waste at the landfill. The event was broadcasted by three local radio stations and TV stations based in Mityana and Kampala (REDS, 2022). This embracement of citizen engagement could strengthen the relationship between the municipality and the informal waste sector, in addition to spreading awareness about plastic waste recycling.

It is important to note that discourse and ideation is an iterative process, while the core intentions should stay intact. To illustrate this, during the field trip to Uganda in April 2023 the aim was to assemble and implement a plastic shredder in the facility in Mityana. However, there were multiple issues with the locally produced shredder parts, and the shredder could not be assembled as is. An easy solution to the technical challenges could have been to produce and import machine parts from Norway. However, this contradicts one of the project incentives as the aim was to source and build the machines locally. The new input resulted in problem solving and coming up with new ideas to solve these challenges without compromising the project incentives (Langseth, 2023). This shows how the discourse dimension can be used as a tool in

decision making processes to come up with and alter initial ideas and still achieve the desired outcomes.

To address whether the project can be considered responsible, it needs to be assessed through the TBL. This means that the project must be considered sustainable by integrating economic performance, social inclusiveness and environmental resilience (Geissdoerfer et al., 2017). To conclude, firstly, the project aims to boost economic performance by developing machinery that increases the quality and volume of processed plastic waste. A business model related to technological solutions will also result in job creation and stimulation of the local economy, in addition to potentially increasing revenue for plastic waste collectors. Secondly, the project heavily depends on collaboration and co-creation with various stakeholders which ensures social inclusiveness. Lastly, by developing a system for plastic waste management the project supports removing plastic pollution from the environment. Based on this one could argue that the SUWASO project intends to create value across all the layers of the TBL. If successful in implementing a sustainable business model based on the developed technological solution, the project fulfills the criteria to be considered a responsible innovation project.

5.2.2 Dar es Salaam, Tanzania

The main aim of the recycling project in Tanzania was to support the UN's Sustainable Development Goals (SDGs). The project started out as an innovation competition where eight student teams from NITO worked to find an innovative solution to manage the plastic waste pollution in Tanzania through a recycling container, in addition to creating local value by creating new jobs (NITO, 2022). The idea behind the plastic recycling station was to tackle local challenges of urbanization that lead to an increased volume of plastic waste, while the plastic waste management efficiency decreases. In addition, the project aims to tackle a rising unemployment crisis among young people in Tanzania (Ingebo & Osborne, 2022). As described in Chapter 1.3, plastic pollution, and poor waste management cause negative impacts on ecosystems both on land and sea, infrastructure, and human health. The project objectives therefore have the potential to support SDG 1, 3, 6, 8, 9, 11, 12, 13, 14, and 15 (UN, n.d.).

Figure 5 - Sustainable Development Goals (UN, n.d.)

The solution can be argued to be based on the project's contextual knowledge. The winning student team knew that the beach in Dar es Salaam was heavily polluted with PET-plastics, which became their target area. This contextual knowledge became important in the decision-making process. The student's solution was to create filaments of PET-bottles that could later be used to create new products through molds and 3D printing, and this way increase the value of plastic waste (NITO, 2022). Respondent R further informed that one of the goals was to produce a valuable product that could be sold on the market, where one of the concepts was rain gutters for collecting rainwater (Respondent R, 03.04.2023):

> *"So, it was NITO that started a student competition and the students who won had a concept where they tried to create rain gutters out of plastic. That was their goal, so that they could have a product that could possibly be sold on the market, and there was also the idealism behind it that they could collect rainwater".*

However, the project met obstacles that could be related to a lack of proper mapping of the territoriality dimension. Respondent R mentioned that one of the biggest challenges within the project was a lack of preliminary research due to lack of time (Respondent R, 03.04.2023:

> *"It probably has been the biggest challenge in this project. We only had a short amount of time to do preliminary work… The winner was announced by the end of January, and it was far too short time after the winner was announced to prepare to both buy and test the equipment. We didn't get to test it [equipment] in Norway and had far too little time to find out more about the plastic and how difficult it was to recycle".*

The lack of preparation resulted in challenges as PET is a hard material to recycle, and the intended equipment was not suitable for recycling PET. Respondent R said that as a result, the

project ended up trying to recycle different plastics such as HDPE and PP. He further informed that it was not an issue to get access to HDPE and PP, but the amounts of these plastics are less than PET and they are harder to identify (Respondent R, 03.04.2023). This illustrates the importance of mapping out the project's territoriality, as the project had to move away from the intended idea of recycling PET due to a lack of sufficient preparation time. Details about the technological solutions will be discussed further in Chapter 5.3.2.

Seen through the TBL the project aims to achieve economic performance by increasing the value of plastics through creating sellable products. In addition, the recycling station will create new jobs supporting the local community. However, the project is struggling to create a viable business model and the recycling container has not had much production in the last year (Respondent R, 03.04.2023). Regarding environmental resilience, the project in Tanzania aims to reduce plastic pollution through recycling. This is a step towards supporting the SDGs by building plastic waste management systems that reduce negative externalities on the environment and human health. Lastly, Respondent R shared that they want to engage the local community both in spreading awareness and collecting plastics (Respondent R, 03.04.2023). In addition, the project works towards social inclusiveness by engaging students to find solutions for the plastic pollution problem. However, it was not clear if there had been any co-creation or citizen involvement related to developing solutions based on local needs.

Based on this, one can see that the project's intentions are in line with the TBL, but steps need to be taken to fulfill these intentions. This illustrates how the discourse dimension can be used as a tool by highlighting potential problem areas that need further improvement. The project has yet to develop a viable business model and is currently not creating economic value. With low production there are also fewer incentives for plastic collectors to collect and sell plastics to the facility, reducing the intended environmental impact. One could also argue that the project could increase social inclusiveness by involving local actors and citizens in the development process, which in turn, could increase the chances for success by developing solutions tailored to local needs. This illustrates how the project's contextual knowledge can impact the discourse dimension. Without sufficient knowledge it can be harder to make well-informed decisions, which could result in additional challenges. However, the challenges faced by the project create learning experiences that can increase their contextual knowledge, and thus increase the ability to navigate the dynamic environments of an innovation project.

5.2.3 Bamako and San, Mali

Conversations with the project owner from Strømme Foundation, Respondent U, informed that the main intention behind the project in Mali is to collect plastics to make school desks. The desks are produced locally where additional incentives are to create jobs to tackle a rising unemployment rate of 50%, targeting young people and women (Respondent U, 09.05.2023; Yasien Ahmed et al., 2022). The goal behind the desk production is to create a market for plastic desks rather than wooden desks. Respondent U informed that Strømme Foundation has its own schools and educational programs in Mali where they provide education for uneducated children. The goal is to accelerate the children's education over a nine-month period, equipping them with sufficient knowledge to be placed in normal schools. An issue related to this is that there is a lack of school desks in the educational sector, and that traditional wooden desks contribute to desertification. The narrative behind the project is therefore to provide a cheaper and more sustainable desk on the market (Respondent U, 09.05.2023).

The project knew that there are challenges with pollution from LDPE bags, and that there are already structures in place for recycling harder plastics. The technological solutions needed for producing the school desks are developed by a for-profit organization, Yamba D that has its own production in Ouagadougou, Burkina Faso. The feasibility study revealed that a plastic melting unit from Yamba D was a recommended solution to create green jobs in the waste management sector for several reasons. Firstly, the production method is simple and requires minimal training. Secondly, it was possible to make desks that are widely used in the school system (Zoure & Nonguierma, 2019). Thirdly, more than 25 kg of plastic bags is needed to create three school desks, resulting in reducing significant quantities of plastic waste (Svendsen et al., 2019). Other benefits were related to cost effectiveness and reduced emission of greenhouse gases compared to wooden desks. This solution was therefore able to create jobs both in regard of plastic collection and production (Zoure & Nonguierma, 2019).

The project's contextual knowledge identified a deficit of school desks in both Bamako and San. Further, it was known that the technological solution from Yamba D was suitable for school desk production and that this could create jobs in line with the project's intentions. Based on this knowledge, the project decided to purchase and implement the technological solution from Yamba D at the facilities in Bamako and San (Respondent U, 09.05.2023). Further, the market analysis from the feasibility study included a list of potential customers, but did not include data on price expectations or willingness to pay (Zoure & Nonguierma, 2019). This means that the economic market potential for school desks is unknown, which could impact the

economic layer of the project's business model, which is discussed in Chapter 5.4.3. This illustrates how the contextual becomes important in the discourse dimension, as this creates the fundament for making informed decisions.

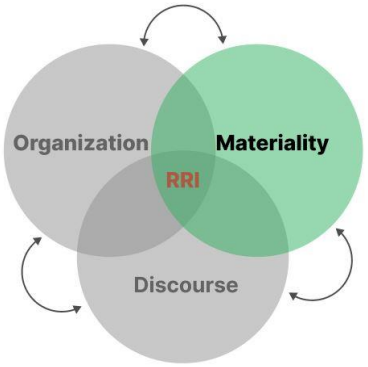
Regarding co-creation, Respondent U stresses the importance of using local competence rather than using the expertise that is localized in Norway. He informs that most decision making is done by local employees and partner organizations, while Strømme Foundation is looking for ways to provide financing. He further informs that Strømme Foundation and the project are in close cooperation with the local government: *"The government assesses and approves all our plans… and they have kind of been involved from the start"* (Respondent U, 09.05.2023). The project has previously held workshops where the government is invited to take part in defining and developing project activities. He further informs that every time they plan to travel to Mali to visit the project, they always contact the government first. He continues to explain that Strømme Foundation is a rights-based organization that works with local groups and seeks to promote their rights, and that they usually try to make governments take responsibility. However, in countries such as Mali where the government lacks the capital to take responsibility, they rather aim to support the government in achieving their goals given that they are aligned with the SDGs or similar aspects (Respondent U, 09.05.2023).

The feasibility also stresses the importance of municipal involvement when implementing the two facilities in Bamako and San. The operationalization of the facilities cannot be achieved without the involvement of the municipalities and technical staff of the sanitation services. The reasoning behind this is that the municipality is responsible for ensuring the responsible management of municipal waste, while the technical staff of sanitation services is responsible for any social and environmental impact caused by the facilities. However, the implementation of the facilities aims to create positive impacts by hiring vulnerable groups. Women represent 50,4% of the population, where 73,2% of all women have not received any form of education. Most of the country's poverty situation consists of women of childbearing age and children under 15, which is around 70% compared to only 19% of men between 15 and 49 years old (Zoure & Nonguierma, 2019). Hiring women and young people therefore social inclusiveness, which is in line with the TBL. As discussed in Chapter 3.4, the collaboration with the municipalities and actors such as SFC and S3A, in addition to involvement of citizens, could result in positive effects such as citizen empowerment, and promotion of co-creation of services that benefit both the facility and local needs.

Assessed through the TBL, the project aims to create economic value by creating school desks to be sold on the market. The facilities will also promote economic gains through job creation and incentives for plastic waste collection. As the workers in both facilities consist of women and young people, it also promotes social inclusiveness. Lastly, the project aims to create environmental benefits through the reduction of plastic waste pollution. As a result, like the other cases, one could argue that the project in Mali could be considered a responsible innovation project through the discourse dimension, as it aims to create value across all aspects of the TBL. To ensure that the project intentions are met the project needs to focus on developing a viable business model based on the chosen technology to ensure economic, environmental, and social value creation.

5.3 Materiality – Resources and Technology for Plastic Waste Management

This chapter discusses the materiality dimension which concerns the innovation processes of technological solutions and resource utilization. The processes in the three projects are analyzed through the design thinking method to discuss whether the solutions have been effective in meeting the end-users needs, see Appendix G. Lastly, I assess potential improvements that can be made to improve the technological solutions to ensure long-term sustainability.



5.3.1 Mityana, Uganda

Based on the design thinking method, the starting point for any innovation process should be the empathy phase, where one investigates and assesses the user's perspective, current methods, and needs (Appendix G). This highly correlates with the project's territoriality as this involves mapping user surroundings and gaining important insight. In this case, our solutions are targeted toward increasing value for the informal waste sector. As a result, PWBCs are identified as key users, while other plastic recyclers will be considered as potential buyers of recycled plastics (Langseth, 2022).

As discussed in Chapter 5.1, some key takeaways are that PWBCs struggle with high transportation costs, low margins, and fluctuating prices. Ideally, they would want a shredder, washer, dryer, and extruder to create plastic pellets and increase efficiency. Conversations with Respondents O and Q also supplied important insight. The representative at Coca Cola said that they would be able to pay higher prices for pre-shredded plastics of a certain quality

(Respondent O, 06.04.2022). Respondent Q from Quality Plastics Limited informed us that their offered prices depend on transportation costs, and that a truck with the capacity of 20 tons is usually only filled with around 1,5 tons (Respondent Q, 07.04.2022).

The insight from the empathy phase allows us to define an actionable problem statement that would be the basis for generating a scope of solution concepts. While the overall problem is to reduce plastic pollution it is easier to tackle the problem if it is divided into smaller and more concrete problem statements. In the SUWASO project, one can name three actionable problem statements. First, plastic waste management in the informal sector has low profit margins. Secondly, plastic waste management has low efficiency due to a lack of suitable equipment. Thirdly, machines are hard to maintain and repair due to a lack of local resources and competence. It was decided to set up a plastic recycling facility in Mityana, equipped with a washing system, shredder, and drying system. This would not only increase efficiency and quality of collected plastic waste, but also compress the plastics to increase transportation volume (Langseth, 2022).

In regard to developing the machines, one key aspect was that they should be sourced and built locally. During the first field trip to Uganda, we visited a local engineering company in Kampala to assess what tools, production methods and materials that were available. The workshop was equipped with basic metal work machines such as a milling machine, lathe, plate bender, various cutting machines, MIG/MAG/TIG/SMAW welding, column drills etc. It was discovered that access to certain materials, such as hard grade steels, could be problematic as they may have to be imported from other countries. However, it was informed that there were multiple other workshops in the area that could help in ordering specialized materials. It was desirable to produce machines with simple mechanisms so that local workers could repair and maintain the machines themselves. An early idea was to use an open-source design by Precious Plastic as a draft for the shredder, and try to simplify these for easier building and repairs, see Appendix L (Langseth, 2022; Precious Plastic, n.d.-a).

The open-source drawings for the Precious Plastic shredder were sent to two different workshops to get a quotation. Due to the complexity and specified materials needed for the design, the quotations received were extremely high and over double the cost of what production would cost in Norway. This led us back to the ideation phase to discuss other alternatives. It was eventually decided to design new shredder drawings that would require minimal tools and equipment (Langseth, 2022, 2023). A selection of the new shredder drawings designed by Human Brights can be found in Appendix H. The new drawings were sent to six

different companies, but only two companies agreed to provide a quotation. The quotations given for the new shredder design were around 80% cheaper than the design from Precious Plastic, making it a more achievable solution. The quotations from the two companies were similar in price, but it was decided to choose Nakawa Vocational Training College in Kampala, hereafter referred to as Nakawa. The reasoning behind this was that they were slightly cheaper, in addition to engaging and creating learning opportunities for local students in the development process (Langseth, 2023).

During the development process of the new shredder drawings, the prototyping was mainly done through digital drawings. However, to ensure that the shredder could be produced with the tools and materials that were available in Uganda, it was decided to make a prototype in Norway of the shredder teeth. These parts are usually laser cut, but as this is not an option for local production in Uganda it was essential to find an alternative production method (Langseth, 2022). It was confirmed that the teeth could be produced using a stationary drill press, welding machine, band saw, clamps, file, and an angle grinder, and a suggestion for a production procedure was made (Saabye, 2023a). Ideally, the whole shredder should have been prototyped and tested before ordering the parts locally, but this was not done due to insufficient time and budget before the implementation phase of the SUWASO project. As a result, all parts were ordered by Nakawa without further prototyping (Langseth, 2023).

The remaining prototyping and testing phase of the technological solutions took place during the second field trip to Uganda, where the main goal was to build, implement and test the machines. The original plan was to buy and rent tools, materials, and remaining parts, and then assemble the machines locally in the recycling facility in Mityana. A summary of the tools and materials needed was sent to different vendors, but it turned out to be challenging to find one vendor that had all the items in stock (Langseth, 2023). Nakawa could provide most items and was willing to rent us some machines and equipment. However, one problem was that some of the machines were stationary and difficult to transport. In addition, due to time constraints, the list of items provided by Human Brights Engineering did have a high enough degree of specification. It was therefore more challenging for Nakawa to know exactly what to provide. Another issue was that the equipment was used regularly, and it was unfavorable to Nakawa to put it out of business during the duration of our trip. To solve this issue, we were offered to rent their equipment while using their workshop in Kampala instead of transporting it to Mityana. This turned out to be beneficial as we gained access to a complete workshop that made it easier to perform necessary modifications during the building process (Langseth, 2023).

When arriving at Nakawa in April 2023 we were introduced to the principal. We received great support and were promised support and guidance from one of the teachers, who was a mechanical engineer, and a previous student that would join our workshop team. In addition, four students would be available to support us if needed. During the first day at the workshop in Nakawa, we started to inspect the produced shredder parts and multiple deviations from the drawings were discovered. Details about the deviations are described in Appendix I. This caused challenges related to building and testing the machine but could also affect our relationship with the school and ability to collaborate. We notified the teacher that was there to support us, but he claimed that the parts were produced according to the drawings. We therefore showed the deviations to the teacher and explained the importance of accuracy for the machine to operate as intended. As Nakawa could be a valuable actor in future project work, both for producing spare parts and additional machinery, and technical support, we did not want to cause any conflict to harm our relationship. We therefore proceeded to look for solutions to rectify and modify the parts, and alter the shredder design to fit the necessary changes (Langseth, 2023).

It is important to note that Nakawa is considered a professional vendor and should therefore be able to produce parts according to simple machine drawings. During the rectification and modification process we observed that the competence and resources needed to produce parts within the drawing specifications were present. It is beneficial for the project to keep collaborating with Nakawa both for further production and technical support in the future (Langseth, 2023). To continue the collaboration, it was therefore important to inform Nakawa about the deviations and the challenges this led to, giving them a chance to correct their previous mistakes in future work. It was agreed that the local project partner, REDS, should communicate with Nakawa and inform them that they need to produce parts according to drawing specifications for future orders (Langseth, 2023).

With engagement and help from both teachers and students at Nakawa, we were able to make the necessary alterations to assemble the shredder. The modifications that were made are described in Appendix J. During the modification processes we repeatedly went back to the earlier phases of the design thinking method to find new ideas and solutions for improving and testing the shredder. The main issue with the deviations and modification process was not the parts themselves, but that it cost us a lot of time that could have been spent on developing and building a washing and water cleaning system and a drying system. However, during the process we also gained positive experiences through co-creation with Nakawa. Multiple

teachers came up with ideas for improving the shredder design (Langseth, 2023). This was a very positive encounter as it showed the benefits of co-creation and local involvement. Ideally this could lead to Nakawa creating a new and improved shredder in the future, which can be sold to other actors in Uganda to increase the efficiency of plastic waste management.

Another challenge related to the development process was to find a coupling and a gear that matched the needed specifications. In addition, the prices for these parts were very high due to the dollar rate and taxes. We were eventually able to buy a single-phase motor, gearbox with a ratio of 1:40, and coupling from a local vendor. Both the coupling and gearbox were used, and it was hard to determine the state of the gearbox and its expected lifetime. As we struggled to find a gearbox it was discussed to fabricate a gear from scratch using motorcycle parts, or by adding a flywheel to the shredder. This could be a good alternative in the future if a gearbox is hard to source (Langseth, 2023).

After assembling the shredder, it was tested on the grid at the workshop in Kampala (240V). Initially we had some issues starting the shredder as the fuses in the workshop could not handle the power needed to start the motor. After connecting the motor directly to the fuse box, we were able to run the shredder without any issues. However, when feeding the shredder with plastics the safety mechanisms kicked in too quickly, shutting down the shredder. This was due to a safety bolt that was designed to break at a certain load. The bolt size is calculated based on the bolt material and the force where it is intended to break. This became a minor issue since we were provided with bolts where the quality of the material was unknown (Langseth, 2023). This aspect is something that could be of importance for future projects, as it could be hard to design safety mechanisms, or other critical machine parts, when there is a lack of information on the materials acquired. However, we were able to rectify the issue by buying bolts in another known material and recalculating the bolt size needed. After getting the right bolt we were able to shred PET-bottles while testing the shredder at the grid in Kampala. Through all the challenges encountered we saw the importance of collaboration with local actors. Without local actors with the knowledge of where to get the necessary resources of a certain quality, the modification process would have been significantly more challenging (Langseth, 2023).

Picture 1 - Shredded PET-bottles (Langseth, 2023)

Picture 2 – Testing Shredder (Langseth, 2023)

After successful testing in Kampala, the goal was to transport the shredder to the recycling facility in Mityana to implement and perform further testing of the shredder. The facility in Mityana only has access to a single-phase grid, and the shredder was therefore designed to operate using a single-phase power source. When attempting to test the shredder at the facility in Mityana we met additional challenges. During the first test, the shredder was unable to start. After some troubleshooting it was discovered that there was a large voltage drop across the power lines into the facility. This is due to the power lines being shared by other community members. Measurements on the power outlets showed that we were not getting high enough voltage. The highest voltage was measured at 178V, but it varied greatly throughout the day and during peak hours it could be as low as 148V. At this voltage, we force-started the motor and measured 136 V, meaning the motor itself caused a 12V drop on the entire grid. There were also multiple power outages, and we were informed that these could last up to 4 hours at the facility location (Langseth, 2023). This shows how the available infrastructure impacts the development and operation of technological solutions, and this should be considered during the development process.

To overcome this challenge, we needed to go back to the ideation phase to find potential solutions. Due to a limited budget, it was not an option to connect to a three-phase grid as this was expensive. Further troubleshooting revealed that the motor could be the main issue, rather than the shredder box itself. The motor was very simple and was labeled to deliver around 2800W. During testing in Mityana the output was calculated to be only around 500W. In addition, the motor was only equipped with an operating capacitor of 5µf, which is considered very low. To ease the power needed from the motor we proceeded to minimize friction in the

shredder itself, and therefore lower the power needed for the shredder to run. These modifications are described in Appendix J. We were able to get the shredder to run, but the motor still struggled to power the machine when feeding it with plastics. A suggestion was therefore to replace the single-phase motor with a three-phase motor that could be modified to run on single-phase, in addition to replacing the gearbox with a new one with a ratio of 1:60. Later it was also discussed to increase the voltage to the facility by redirecting two powerlines that would not be shared by other community members. As there were limited opportunities to test the shredder in Mityana, the production rate for shredding plastics is unknown (Langseth, 2023).

Due to the unforeseen challenges with building the shredder there was a shortage of time to come up with a design for the intended washer and water cleaning system. With some pre-ordered parts from Nakawa and additional plumbing parts sourced locally in Mityana, we were still able to design and assemble a washing system and a prototype of a very simplified drying system. These systems are described in Appendix K. After initial testing on the water system, we discovered multiple leaks. One issue was caused by too high water from the water pump, causing the tanks to overflow. Minor leaks were mainly caused due to insufficient sealing between the various connectors. To reduce the water pressure a long hose was connected from the water pump and to the intake tank for dirty plastics. We also needed to change the open tank system to a closed tank system. This was done by connecting the tank lids with bolts and silicone. Leaks from the various connectors were sealed using LDPE bags as thread tape. Additional testing revealed that the water pump was mounted too high, and that the water pressure became too low after installing the long hose. This could easily be rectified by lowering the pump and reducing the length of the connected hose. We did not have sufficient time to perform these corrections ourselves during the field trip, and they will therefore be performed by the locals that will be hired to work at the facility (Langseth, 2023).

To conclude, through the innovation and development process the SUWASO project has shown that it is possible to develop technological solutions that are adapted to suit local conditions and available resources. A prerequisite for succeeding seems to be the degree of contextual knowledge gained by the project, as the development processes were based on the production methods and resources that had been mapped during the first field trip to Mityana. Even though some materials are not ideal, they could still be utilized to create functional machines that increase efficiency in plastic waste management. As an example, the shredder parts are made

from soft steel which is not considered the most suitable material as it wears out faster and requires a more frequent replacement than higher quality steel (Langseth, 2023).

It is still important to note that by using locally sourced materials one can promote long-term usage by ensuring that the resources and competence needed to maintain and repair the machines are available. This would not likely be the case for more complex or imported machines, as we experienced that access to more complex parts and materials was highly restricted. The same results would have been challenging to achieve without sufficient insight from the territoriality dimension and the initial phases in the Design Thinking method. Further, by including various local actors such as PWBCs, students, and teachers in the innovation process, we gained valuable insight for both designing and developing the technological solutions. Collaboration with these actors provides insight into the empathy phase but also valuable feedback from the prototyping and testing phase. These experiences are extremely valuable and can be used to further improve and tailor solutions to local user needs. An additional reward gained through co-creation is the opportunity to increase engagement and competence related to plastic waste management, supporting long-term solutions.

Based on this one can argue that the SUWASO project has been able to create technological solutions that meet user needs. The developed solutions matched the machines that were requested by the actors in the plastic waste sector, while also supporting long-term operation by only using local resources. Still, there are improvements that could have been made to strengthen and ease the innovation process. The project met many challenges and had to return to the previous phases of the Design Thinking method multiple times. Some of these challenges could have been reduced by creating complete prototypes before ordering the parts locally. This way one could assess and test whether the machines operate as intended or if modifications need to be made. However, as the HB shredder design was a response to the initial challenges with the Precious Plastic shredder, there was not sufficient time to do so. In the future it could be advised to add measures for quality control to ordered parts. This could be done by ordering demo parts for inspection or inspecting the quality of produced parts through local partners or high-resolution pictures.

5.3.2 Dar es Salaam, Tanzania

As discussed in Chapter 5.2.2, the solutions in the plastic recycling project in Tanzania are targeted toward reducing plastic waste pollution and creating jobs for young people in Dar es Salaam. Seen from the design thinking perspective the potential users would be actors in the plastic waste management sector and unemployed young people in Tanzania. This is a rather

broad spectrum of users, making it more challenging to gain insight into the users' different perspectives, current methods, and needs. Key insight from the project's territoriality shows that pollution of especially PET-bottles is a huge challenge, in addition to a lack of infrastructure related to plastic waste management (Ingebo & Osborne, 2022). When mapping the project's territoriality, the project did not assess the existing structures and actors in the plastic waste sector. This could impact the empathy phase in the Design Thinking method as one lack sufficient insight to truly understand the users, how they do things, their perspectives, and their needs.

The insight gained from the empathy phase and the project's territoriality could further impact how the project could define an actionable problem statement. The project in Tanzania aimed to reduce plastic waste pollution and create jobs for young people, which serves as an overall problem (Ingebo & Osborne, 2022). However, these are not necessarily very actionable problem statements, and it could be easier to find solutions if they were broken down. From the territoriality and empathy phase the project knew that there was a huge issue with pollution from PET-bottles, high unemployment rates amongst young people, and lack of awareness related to plastic waste management. These could be more actionable problem statements. As mentioned in Chapter 5.2.2, the final problem statement that was given to the students developing solutions was to find an innovative solution to manage the plastic waste pollution in Tanzania through a recycling container, in addition to creating local value by creating new jobs (NITO, 2022).

It was initially Tanzania Explorer that decided to set up a local recycling container due to the plastic pollution problem. With collaboration with NITO, further ideation happened through the students that were encouraged to find a business model and technological solutions that should get the container up and running (Respondent R, 03.04.2023). The student solution was based on insight from the empathy phase as they knew that PET-bottles were one of the main pollutions in the area. The solution aimed to reduce the pollution of PET-bottles by recycling them into filaments for 3D printing, while other types of plastics such as PP and PVC should be melted and recycled into other products (NITO, 2022). Engineers Without Borders joined the project to prepare and install the technological solutions, in addition to helping the students with practical engineering and teaching them about plastic recycling and mechanical equipment (Respondent R, 03.04.2023). The machines that were chosen were a shredder, extruder, and a compression machine from Precious Plastic, in addition to an injection machine, see Appendix

L (Ingebo & Osborne, 2022). Respondent S also informed that the facility was equipped with a 3D printer that was donated from Norway (Respondent S, 03.04.2023).

Related to the design thinking perspective, the machines from Precious Plastic have already been prototyped and tested and could therefore decrease the need for further prototyping and testing of the technological solutions in the project. However, it is important to note that machines still require assembly and testing to ensure that they operate as intended (Precious Plastic, n.d.-b). Respondent S informed that originally EWB was supposed to only install the machines and ensure that they worked as intended, but that the scope expanded to them also buying the machines. It was discovered that there was an entrepreneur in Dar es Salaam that made the Precious Plastic machines, and the original thought was therefore to buy the machines from him (Respondent S, 03.04.2023):

> *"We said 'Ok, we want to get as much ordered from Tanzania as possible and this is really great to buy the machines from this guy. Then we have someone local who can come and fix it'… He was advertising on the Precious Plastic Bazar, and we got pictures of the machines and they looked fantastic"* (Respondent S, 03.04.2023).

A challenge that was pointed out was that since Precious Plastic has an open source and license, anyone could produce and sell the machines. As a result, many vendors advertise for selling these machines, but the quality could vary greatly (Respondent R, 03.04.2023). When the team from EWB arrived in Tanzania to build the machines, it turned out that the machines were not of the quality they thought they would be: *"And then the machines arrived, and they were absolutely not the same as we thought… When we tested them, when we were down there, they didn't really work so well"* (Respondent S, 03.04.2023).

The shredder that was purchased turned out not to be suitable for shredding PET-bottles, which were the intended plastics to shred. There were some attempts to contact the entrepreneur that produced the machine, but he would not answer the phone. After a while the entrepreneur sent a friend to the facility, but he wanted additional money to fix the machine. Respondent S also informed that the access to tools was terrible, and that slowed down the development process (Respondent S, 03.04.2023). This sent the project back to the ideation phase to find new solutions for how they could get the machines to operate. Due to the challenges faced they ended up going back to Norway to get new parts and additional tools. In the end they were able to salvage some of the parts from the original shredder and building a new modified shredder using both original parts and parts from Norway. Respondent S further mentioned that there is

a local branch of ventures that EWB has started in Dar es Salam (Respondent S, 03.04.2023). This means that there is a possibility of incorporating these ventures to ensure that there is someone with engineering experience available if future repairs are needed.

The compression machine was originally ordered by the students from a vendor in India. The machine was sent to Norway, but there was not enough time to test it before traveling to Tanzania. When testing in Tanzania, it was discovered that the compression machine could not get to the right temperatures, and the hydraulic jack was not powerful enough to create sufficient pressure. There were also issues with the extruder where there were issues with incorrect connections between some temperature sensors and a heating element. For the compression machine it was made attempts to modify the machine using local resources. This turned out to be a very time-consuming process as there was limited access to resources and spare parts. Respondent R informed that the attempt to make the compression machine work was successful. However, the machine would not reach the high temperatures needed to create sheets of PET, but it was successful when using PP and HDPE (Respondent R, 03.04.2023). Regarding repairs, the project team trained the local handyman and gardener in Tanzania Explorer. The intention was that he could perform repairs if needed. A challenge was that he was illiterate and relied on physical demonstrations during training (Respondent S, 03.04.2023). A potential issue related to this could be the ability to read repair procedures if more complex repairs are needed.

The team in Tanzania faced additional challenges during the implementation of the machines. Firstly, the extruder machine did not come with any spare parts. During the assembly one of the parts became damaged and it was not possible to repair the part locally. This meant that additional parts needed to be ordered in Europe, causing a delay in the implementation process. Secondly, Respondent S informed that there were a lot of power outages. They could not rely on power, making the work more physically challenging. To get access to electricity they had to plug into a neighboring house. This revealed a safety gap as they did not use any electrical plugs, but rather twisted bare cables and put it straight into the socket. It seemed that this was a common practice, even though the respondent brought cables and other items needed to connect safely (Respondent S, 03.04.2023). This indicates that there is a need for training and spreading awareness related to work related health and safety requirements.

In regards of co-creation the technological solutions were as previously mentioned developed through collaboration between NITO, students from NITO, EWB, and Tanzania Explorer. Tanzania Explorer is the only local actor, but as they are a safari company it is natural to assume that they do not have any specific insight into the plastic waste sector and its specific needs.

Respondent S informed that they had not had any commercial discussions with actors in the market (Respondent S, 03.04.2023). This could result in the implemented technological solution not meeting needs in the plastic waste sector, and therefore not being an optimal solution for reducing plastic waste. This could also affect the possibility of developing a viable business model, which will be discussed in Chapter 5.4.2. Respondent S further informed that one of the employees in Tanzania Explorer has a good network, and that they want to use their new experience to plastic waste management to show that they are doing something good for the society (Respondent S, 03.04.2023). This could be a valuable resource to enable co-creation in the future to tailor the facility to local needs.

To conclude, one could not confirm that the implemented technological solutions fully meet user needs. The machines are tested and suitable for recycling plastics, but as local actors in the plastic waste management sector have not been involved in the development process one could be unaware of important needs that should be considered. The project also experienced challenges with limited access to tools, parts, and materials. This could result in maintenance and repairs being more challenging to perform, and therefore impacting the lifespan of the technological solutions. An additional note is that certain spare parts need to be imported from Europe, which could impact on the finances needed to operate the facility. Based on this, there are some improvements that can be suggested to support long-term sustainable solutions. Firstly, one could gain additional insight from the empathy phase by involving local actors in the plastic waste sector. Secondly, one could consider machines with lower complexity that do not rely on importing spare parts. Lastly, as the project brought machines from Norway, it could be beneficial to test them before implementing them in Tanzania. This could have revealed certain issues in advance, making it possible for the Norwegian team to bring potential spare parts needed, in addition to saving time during the implementation process.

5.3.3 Bamako and San, Mali

Assessing the materiality dimension for the project in Mali was somewhat more challenging as the engineers that took part in the project were unable to travel to Mali due to the corona situation (Respondent T, 04.04.2023). The ongoing crisis in the country has also made it difficult to visit the project (Respondent U, 09.05.2023). For the project in Mali the aim is to reduce plastic waste through school desk production, while providing jobs for women and young people. The end users in this project consist of a women's cooperative that will collect plastic, and a cooperative of young boys that will work in the production unit (Zoure & Nonguierma, 2019).

From the design thinking perspective, the project has already performed a thorough mapping of the project's territoriality, which correlates with the empathy phase. Based on insight from the project's territoriality it was established that actors such as the S3A center and the SFC group were interested in supporting and selling plastics to the recycling unit. This insight is valuable for defining actionable problem statements. For the project in Mali the overall purpose was initially to create jobs and learning experiences for specifically women and youngsters, while contributing to solving the overall waste challenge in Mali (Svendsen et al., 2019). Based on the overall purpose and insight from the territoriality and empathy phase, one can suggest two actionable problem statements. The first statement is to assess how a plastic recycling unit could create jobs and learning opportunities for women and youngsters. The second statement could be to assess how they can reduce pollution from LDPE bags.

For the ideation phase, the project already had the technological solutions from Yamba D in mind. To assess if this could be a suitable solution for the project's purpose, EWB was involved in assessing the current HSEQ procedures and production processes in Burkina Faso. The goal was to improve the processes and procedures. If a feasible solution was met, existing knowledge would be transferred in collaboration with Yamba D to build the recycling plants in Mali (Svendsen et al., 2019). The prototyping phase in this project could therefore be seen as the assessment process, where knowledge obtained could be used as feedback to improve the technological solutions. Respondent T informed that the process in Burkina Faso was simple and that they started the process by describing the process step by step and identifying potential risks. The first conclusion was to implement the lean 5S principles to improve the production process, see Appendix M. The next step was to assess the melting process of plastics as there were a lot of gases that were emitted from this process. This was done by setting up a workshop in Tønsberg, Norway, where they experimented with developing a process with less emissions. This was successful and they were able to create an improved process through temperature control and isolation of the melting pots (Respondent T, 04.04.2023).

When asked about details about the technological solution, respondent T informed that there is not any advanced machinery. The solution consists of a couple of melting pots and a plastic press that looks like an old-fashioned book press (Respondent T, 04.04.2023). This could simplify maintenance and repairs as there are few moving parts that need replacement. The technological solution is developed by Yamba D in Burkina Faso, but the equipment used in the facilities is produced by local workshops close to the facilities. It was further informed that these workshops were able to produce most items needed for repairs, and that there were not

any issues accessing necessary resources. It was confirmed that there would not be any issue doing any repairs locally, and that a prerequisite for the project was that the technological solutions could be built locally (Respondent T, 04.04.2023).

Like the project in Uganda and Tanzania, the project in Mali also met some challenges with electricity. One of the facilities is located close to the grid, but the access to electricity was not stable. Especially during the rainy season, it could be long lasting power outages. The second facility was located far from a connection point, and the connection cost was extremely high. To solve this, it was suggested to make a process where one could run the machinery with a bicycle, but the local workers did not accept this suggestion. Due to the electrical challenges, it was therefore essential to install solar panels to run smaller electrical appliances, in addition to a diesel generator as a backup (Respondent T, 04.04.2023).

In conclusion one could argue that the technological solution meets user needs. The project involved local women to ensure that they were interested in a plastic recycling unit. The technological solution has been assessed and improved to ensure safe production methods, while also focusing on local production and repairs. The project also shows involvement and collaboration with local actors such as the SFC group, Yamba D, in addition to production through local workshops. Based on the resources available it seems like the implemented solutions are suitable for local conditions, indicating a long-term solution. Currently the plastic recycling facilities are only recycling LDPE and potential improvements could therefore be to assess possibilities for incorporating other types of plastics in the facilities. It could also be beneficial to increase the degree of co-creation and involve actors in the plastic waste sector to assess new possibilities.

5.3.4 Materiality Discussion

Based on the three cases discussed, one can see that the materiality dimension is heavily influenced by the territorial and discourse dimension. Where territoriality is about acquiring knowledge about the local context where the project will operate, the discourse dimension builds on this knowledge to explore and discuss potential solutions that align with the project's intentions and criteria. The materiality dimension concerns how innovation processes can be performed based on the available resources and infrastructure. The knowledge gained from the project's territoriality is therefore important as this creates the fundament for making well-informed decisions during the development processes. This creates the basis to ensure that the developed technological solutions can solve the identified problem statement, meet user needs, and that they can operate based on the resources available.

As seen with the project in Uganda, the territoriality was thoroughly mapped by assessing the current state of the plastic waste problem, current practices, needs- and challenges met by various actors, in addition to assessing the availability of resources. Together with the intentions and criteria from the discourse dimension, this heavily influenced the development process of the technological solution that was implemented. As a result, the SUWASO project was able to develop a solution that can contribute to solving the challenges met by the informal waste sector. The intention of producing the machines locally resulted in a co-creation process that engaged local actors in the development process. This contributed to ensuring that the necessary expertise for maintenance and repairs was secured locally. Additionally, by seeing resource scarcity as an influencing factor one could also ensure access to the resources needed to implement the solution. This indicates that what normally would be assessed as a limiting factor can rather be a strength when developing long-term and sustainable solutions. The project faced multiple challenges during the development and implementation process, but due to the local perspective and engaging local actors it seems like these challenges were more manageable to solve.

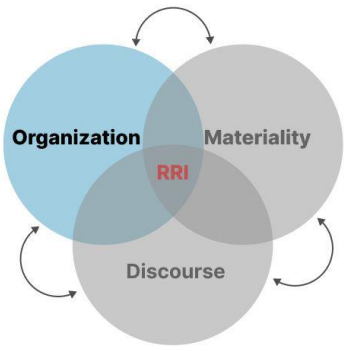
The project in Tanzania faced similar challenges with limited access to tools and materials. However, when compared to the SUWASO project one can see that the project in Tanzania took a different approach when developing the technological solution. The project did not assess specific user needs or resource availability to the same extent before the implementation phase. As a result, the project faced various challenges that became time consuming and more complex to overcome. As the final solution heavily relied on imported parts and tools, this could impact the ability to maintain and repair the machines with local resources. As mentioned by the PWBCs in Uganda, this can result in future risks where the machines break while the competence, resources and capital needed to fix them are absent. This could impact the ability of the implemented machines to become a long-term and sustainable solution. This shows how a lack of sufficient mapping of the project's territoriality can negatively influence the materiality dimension, and cause challenges that might be more demanding to solve.

The project in Mali shows similarities with the SUWASO project where the territoriality was mapped thoroughly. The project assessed the need for setting up a local recycling unit by assessing the waste volumes and current practices in Bamako and San. Additionally, the desire to set up a local plastic recycling unit was assessed through conversations with local actors, resulting in engagement from a local women's group. Like the SUWASO project, the project in Mali had a focus on building the technological solution locally. This resulted in implementing

a solution developed by the local actor Yamba D. The machines were of low complexity and were built with locally available resources. By doing so, the project in Mali could also ensure that the competence and resources needed to maintain and repair the machines are secured locally, supporting a long-term and sustainable solution. The project in Mali has currently not faced challenges related to the implementation of the technological solution. However, the focus on local production and resources may contribute to making potential future challenges more manageable.

As a conclusion, one can see the importance of mapping the projects territoriality. Sufficient knowledge of the plastic waste sector, challenges and needs, and resource availability are important aspects to ensure that the technological solutions are suitable for the local context. For some projects it might be necessary to develop low-complexity solutions, while others might have better access to resources and therefore the ability to implement complex solutions that can process higher volumes of plastics. A well-adapted solution could result in a longer lifespan, which can contribute to increasing the project's success. From a technical perspective this could indicate that the projects in Uganda and Mali could have a higher chance of long-term success, as both projects utilize only local resources. As a final note, when developing the technological solutions, one should also consider that the end products from the recycling process are suitable for local market conditions. Without sufficient market potential, it will be challenging to develop viable business models. Without securing revenue streams the facilities will not be able to operate due to a lack of capital, making them rather useless. This aspect will be discussed in the next Chapter.

5.4 Developing Business Models for Sustainable Plastic Waste Management



This Chapter discusses the last dimension of my analytical framework, organization. The dimension looks at value creation, development of business models, and modes of organizing the facilities that are set up by the three projects. The projects are analyzed through the economic, environmental, and social layers of the Triple Layer Business Model Canvas to discuss whether the business aspect is viable and to assess the environmental and social impacts and benefits caused by the facilities. I proceeded to assess the relationship between the proposed business model and technological solutions. Lastly, I present suggestions for potential improvements and further work.

5.4.1 Mityana, Uganda

Value creation is one of the key aspects related to business model development. When exploring opportunities for value creation, the SUWASO project's territoriality played an important role. The intention was to create a plastic waste management solution for the informal sector to increase efficiency and profitability. From a market perspective it was known that both PWBC and recyclers struggled with fluctuating prices. Further, the PWBC expressed a desire to create a business around plastic waste recycling, but they struggled with lack of capital due to high transportation costs and low margins (Langseth, 2022). Interviews with Respondent O from Coca Cola, and Respondent Q from Quality Plastics Limited shared that they were willing to pay a higher price if the plastic was pre-shredded, but that this was dependent on the degree of sorting, quality, and cleanliness of the shredded plastics. Respondent O further informed us that there was a possibility of making an agreement on fixed prices (Respondent O, 06.04.2022; Respondent Q, 07.04.2022). Key insights from the three previous dimensions will be discussed through the TLBMC to assess value creation on an economic, environmental, and social level (Appendix O).

5.4.1.1 Economic Layer

The economic layer consists of nine building blocks that illustrate how the facility can create value through its offered services, how this value is delivered to the customer, and then how the facility captures value through its financial performance (Osterwalder et al., 2010). A fundamental starting point was to determine who the facility should create value for, and this way identify customer segments. This was determined by using the market perspective described above, in addition to aspects from the discourse dimension. As discussed in Chapter 5.2.1, one of the goals of the SUWASO project is to find sustainable solutions with a strong local context, building and collaborating with existing structures. Based on insight from market research and territoriality, the project found a potential to increase the monetary value of plastics collected by the PWBCs, in addition to providing a better product for recyclers. The main customer segments for the facility in Mityana will therefore be recyclers, where the PWBCs will be suppliers and key partners (Langseth, 2022).

The value proposition offered by the facility is to reduce plastic waste pollution by buying collected plastic waste, and recycling this to clean plastic shreds. The end-product will be sold as raw material to recyclers and other production facilities. Shredded plastics takes up significantly less space than un-shredded plastics, making it possible to increase transportation weight by several tons, and therefore lowering costs and decreasing the environmental footprint

of the plastic recycling process (Table 3, Appendix N). By reducing transportation costs and increasing the value of plastic, the facility can offer the PWBCs a fair price that increases their current margins (Table 4, Appendix N). The offered product can reduce production costs for the facility's customers as plastics bought from the facility require less processing than buying directly from the PWBCs. Additionally, a potential future agreement on fixed prices between the PWBCs, the facility, and the recyclers can contribute to a reduction in local price fluctuations, resulting in a more stable access to capital (Langseth, 2022). This model depends on collaboration between the actors in the plastic value chain, and strong and personal customer relationships are required. Calculations indicate that the facility can be profitable assuming a production capacity of 29kg/h and a minimum of 144 operational hours a month, or 26kg/h with 160 hours per month. All calculations are shown in Appendix N, while a representation of the economic layer is shown in Figure 18, Appendix O.

For the business model to be sustainable and viable over time there are other aspects that need to be considered. Firstly, one needs to ensure access to key resources such as plastic waste, machinery, electricity, employees, and knowledge. These resources are used to perform the key activities needed for both daily operations and growth (Osterwalder et al., 2010). Due to a limited budget the facility aims to initially hire three employees, a manager that oversees daily operations and growing the business, a technical lead that is responsible for any maintenance, repairs and improvements needed, and a security guard. The daily tasks of shredding, washing, drying, and transporting the plastics will be shared among the three. As a result, the facility will have a flat and organic structure where changes can be made quickly, and tasks can be rotated between the employees as needed. The project's local partner, REDS, will take on the role of an overall supervisor to monitor work dynamics and the facility's progress (Langseth, 2023). Another important activity is to look for opportunities to strengthen and grow the business, where an approach toward formalization of the informal sector could be an important aspect.

There is already a degree of formalization in Mityana as multiple recyclers have organized themselves into a community-based organization. This shows a potential to collaborate with the cooperation and discuss agreements such as prices and types of plastics that can be delivered to the facility. Mutually beneficial agreements between the PWBCs and the facility could encourage other individual actors to join the cooperative to get the same benefits. This can further strengthen the cooperation by providing enough members to get access to the potential cooperative funding that the municipality provides larger community groups. With increased access to capital this could in turn strengthen the facility by increasing the plastic flow, and

potentially increase efficiency and revenue through further collaboration. If good results are achieved, one can proceed to discuss additional agreements with the municipality to increase the efficiency of plastic waste recycling. This could for example be through access to additional capital from the municipality to expand the business, or by encouraging development of new policies that supports and strengthens the informal waste sector in Mityana (Aparcana, 2017; Langseth, 2022).

Basing the business model on a network and collaboration between the current actors in Mityana can open for a greater degree of co-creation and social innovation, which can result in improved and more long-lasting outcomes (Voorberg et al., 2015). This will involve a network of key partners such as Nakawa VTC, the municipality, REDS, and other suppliers, where developing and maintaining good relationships are essential. However, the long-term goal is that the facility will operate locally and without future involvement from the SUWASO project. The proposed business plan and the intentions behind the facility will therefore be shared with the future employees, but it is eventually up to the hired workers to develop and adapt the business model as they see fit. The goal is to illustrate how collaboration can result in benefits throughout the sector through increased revenues, efficiency, and stability, and hopefully encourage the workers to work towards achieving these goals. Lastly, it is important to note that the viability of this business model cannot yet be confirmed, as the facility has not currently started production.

5.4.1.2 Environmental Layer

The environmental layer assesses the facility's environmental impact through its resource utilization, production activities, distribution, and impacts from the use and disposal of the product (Joyce & Paquin, 2016). As the main objective of the plastic recycling facility in Mityana is to reduce plastic pollution, one can argue that a driver for creating a sustainable business model is based on attending to negative externalities caused by others (Jørgensen & Pedersen, 2019). Assuming a production of 30kg/h and working 160 hours per month, the functional value from the facility is collecting and recycling 4.800kg of plastic waste every month. However, the amount of plastics recycled by the facility will depend on the production rate of the shredder. The use phase shows impacts caused by the customers using the offered product. As we are selling to recyclers this means that they use energy to further process the plastics. The end-of-life can be seen as end-products produced by the recyclers and sold to consumers. If these products are incorrectly disposed of, this can result in plastic pollution or emissions from burning waste. However, plastics can be recovered and recycled again, creating

a more circular lifecycle. The distribution of products causes emissions from transport, in addition to potential packaging. The facility production uses electricity from the local grid, but has a low environmental impact as 90% of the electricity in Uganda is produced by hydropower (ERA, 2022). The washing system is designed to clean and reuse the water to minimize water usage. Dirt and sediments from the water will be manually removed and disposed of. However, both the water and the sediments are likely to contain microplastics which can leak into the environment (Langseth, 2022, 2023). A representation of the business model's environmental layers is shown in figure 19, Appendix O.

As the resources used during production will consist of various types of recovered plastics such as PET and HDPE, this will contribute to decrease environmental pollution of plastics, causing a positive impact. The facility also contributes to less emissions of greenhouse gases as less plastics are openly burnt. By providing shredded plastic to recyclers and producers the facility can reduce the demand for virgin plastics, therefore contributing to lowering emissions from virgin plastic production. Additionally, all machines used during production are sourced and produced locally and the emissions are likely to be lower compared to imported machines. The project has not performed a Life Cycle Assessment or measurements on eventual emissions. However, it is natural to assume that the reduction of emissions from recycling plastics is significantly greater than emissions from production and distribution (Langseth, 2022, 2023).

5.4.1.3 Social Layer

The social layer looks at the social impacts and benefits caused by the facility (Figure 20, Appendix O). The aim is that the facility can create social value by removing plastics from the environment and creating additional streams of income for the community, therefore enhancing quality of life. The end-users that receive social value from the facility can be identified to be both customers, employees, and citizens. These actors will benefit from reduced pollution by gaining a cleaner and safer environment. The outreach is local to strengthen local networks and spread awareness. Another long-term aim is to form a mutually beneficial relationship between consumers, PWBCs, and recyclers. This can aid to strengthen the societal culture by spreading awareness related to plastic waste management and developing a culture for cooperation to achieve a clean environment. As the business model is built on collaboration, this can engage the local community through close relationships with the value chain. There are also possibilities to run local sanitization campaigns to engage and educate the community about plastic waste management (Langseth, 2022).

The facility seeks to create a positive workplace that creates value by including the informal waste sector. The employees should be heavily engaged in decision making regarding the operation of the facility, and collaboration with stakeholders is important. Conversations and interactions with the various actors during the project have shown generally positive feedback and attitudes towards the plastic recycling facility. The municipality has shown gratitude towards the project, and the informal waste sector has shown both engagement and willingness to cooperate to increase the efficiency of plastic waste collection and recycling. The machine development further resulted in cooperation with Nakawa Vocational Training College, where both students and teachers were enthusiastic and engaged in the development of the plastic shredder. This experience may have contributed to building competence that can be utilized to build additional recycling facilities and machinery, which in turn will have a greater impact on local societies. Based on these factors one can see many potential benefits from the facility through community engagement, increased cooperation, in addition to job creation that can reduce poverty (Langseth, 2022).

However, there are some potential impacts that may occur. As the facility is run by an NGO it could potentially create mistrust among citizens towards the municipality regarding plastic waste management. Additionally, if the facility is unable to fulfill the expectations from the municipality this may reduce the current support towards the project, weakening an important relationship. Lastly, as the business model aims to collaborate with the plastic waste cooperative, this may create a conflict between the PWBCs in the cooperative and the PWBCs who are not (Langseth, 2022). It is not certain that these impacts will occur, but they are important to keep in mind so that steps can be taken to reduce the risks of creating conflicts and negative impacts.

5.4.1.4 Relationship between the business model and technological solutions

The development process of both the technological solutions and the business model in the SUWASO project has happened simultaneously, with iterative revisions. There has been an emphasis that the total solution is fit for local market conditions. Discussions regarding potential technological solutions have therefore also resulted in discussions regarding the business model and market potential. As an example, one of the initial ideas was to create a recycling and production facility to produce a plastic product fit for the market. However, after assessing the market structures it was discovered that there was a demand for shredded plastics and plastic pellets. Based on this insight it was decided to downscale the facility to plan to just shred, wash and dry plastics, and sell directly to bigger recyclers (Langseth, 2022).

Minor analyzes were performed using the Value Proposition Canvas to assess if the proposed solutions could meet stakeholder or user needs. The results from these analyzes were discussed with REDS to get additional input and ensure local market fit (Langseth, 2022). Based on the discussions from the territoriality, discourse, materiality, and organization dimension there is a seemingly good alignment between the local market conditions, marked needs, technological solutions, and the proposed business model. Furthermore, the discussions of the TLBMC show a potential to create positive financial performance, in addition to environmental and social benefits (Appendix O). These results are in line with the TBL and intentions from Chapter 5.2.1. However, they cannot be confirmed until the facility starts production, and the long-term results can be evaluated.

Based on the results from the economic, environmental, and social layer of the TLBMC, there are several suggestions for potential improvements and further work. Firstly, to increase revenue one could consider adding additional streams of income. One way to do this could be to rent additional services to other businesses or projects. For example, the facility may provide mechanical services to other businesses and projects in the area. Another example could be to collaborate with the municipality and provide workshops to help spread awareness about plastic recycling in the local and surrounding communities. Secondly, from the environmental perspective it could be recommended to improve the washing and water cleaning system to reduce the risk of microplastics leaking into the environment. A potential solution could be to research the possibility of implementing a pyrolysis oven to burn the microplastics in the sediments collected from the washing process. Additionally, the collection of PET bottles has previously not been profitable for the PWBCs. Based on the calculations in Appendix L, the facility can achieve the same profits from both PET and HDPE. As PET bottles are one of the major contributors to plastic pollution the PWBCs can be encouraged to collect and sell PET bottles to the facility, and therefore reduce this pollutant while earning profits. Lastly, if any social conflicts were to occur, it could be beneficial to have potential measurements planned to reduce these conflicts and rebuild strong relationships with the project's stakeholders.

5.4.2 Dar es Salaam, Tanzania

The project in Tanzania is still working on developing a viable business model for the recycling container, focusing on the informal sector. Respondent R informed that the person behind Tanzania Explorer is an idealist that seeks to create awareness around plastic waste recycling. It seems like the main goal has been targeted towards awareness and cleaning up the surrounding beach from plastic waste pollution, rather than focusing on business model

development (Respondent R, 03.04.2023). As a result, there has been a lack of market research to assess the market potential and customer segments. However, there have been some suggestions for a business model which will be discussed through the TLBMC (Appendix P).

5.4.2.1 Economic Layer

The general idea behind the proposed business model is to collect plastic waste in the local neighborhood through plastic waste collectors. When delivering their plastic to the recycling station they will get a form of credit per kilo. The credits can later be traded in for products and the plastic collectors can choose to sell these products themselves for a profit. The recycling station will recycle and process the plastic waste to sellable items by a specially trained "station team". The sellable products can then be sold either locally or globally, but the products sold by the recycling station must be different from the products traded with the plastic collectors. Profits from sales will pay the salaries for the station team (Ingebo & Osborne, 2022). The intentions behind this idea might be good, but there are some problem areas. Firstly, the project has not defined a customer segment, and it is therefore unclear for whom the recycling station should create value for. This makes it challenging to find a sellable product as it is hard to assess if this product correlates with the needs and wants of the customer segment. Secondly, as a result one cannot guarantee any sales or profits needed to cover the operational costs of the facility. Lastly, paying plastic collectors with credits rather than money may not cause sufficient incentives for delivering plastics to the recycling station. A representation of the project's current business model is shown in figure 21, Appendix P.

Respondent R mentioned that rather than spending time in front of a computer creating business models, he would rather take a more practical approach. His idea is to be in the field, think of potential ideas, and then produce potential products and just test them in the market: "*If the product won't sell in a certain amount of time, there is probably not a business around it*" (Respondent R, 03.04.2023). One of the first ideas was to produce rain gutters made of recycled plastics. The main intentions were to use PET-bottles, but testing revealed that recycled PET became too brittle, making it challenging to create gutters with the right material specifications. Another idea was therefore to produce PET toys or other products that could be traded with the collectors (Respondent R, 03.04.2023). Respondent S also informed that the recycling container made plastic tiles, in addition to some 3D printed jewelry. They were able to create earrings that looked very nice, but the respondent was unsure if this was a sustainable business model as it is an expensive process (Respondent S, 03.04.2023). The recycling container is currently

not in production and has not been used for the last year due to the lack of a viable business model (Respondent R, 03.04.2023).

As the project seeks to have a more diversified selection of products, this would also require a wider selection of key resources, activities, and partners. Based on the current knowledge of the project's business plan, a suggestive value proposition could be to reduce plastic pollution by creating a selection of recycled plastic products. Like in the project in Uganda, the key resources would mainly consist of the recycling container, plastics, machinery, employees, and knowledge. However, a wider range of products could require a larger selection of machines. Some machines, like the 3D printer, are more complex which can result in higher maintenance costs. In turn, this would require knowledge of all the various machines, in addition to the various product specifications. Additionally, the recycling station plans to offer different products to the plastic collectors and the customer segment. This could require some additional work with sorting and administration.

Respondents R and S did not have any knowledge about the actors that are intended to deliver plastic to the facility or if these actors were organized in some way. Respondent R mentioned that one of the intentions is that the unemployed or poor can add to their income by collecting plastics and selling this to the facility (Respondent R and S, 03.04.2023). Taking an approach to formalization and encouraging the plastic collectors to organize themselves in a cooperative could be beneficial for both the recycling container and the plastic collectors. This could open a possibility for cooperation between the cooperative and the recycling container, where agreements can be made based on both the recycling station and plastic collectors' needs. Formalizing the informal waste sector could additionally lead to recognition from the municipality, which could result in access to capital. Municipal embracement may lower participation costs, leading more people to join the informal waste sector (Ayeleru et al., 2020; Voorberg et al., 2015). This means that the recycling container would gain access to suppliers of plastic waste, while contributing to improving working conditions for the informal sector.

In conclusion, the project has not yet been able to create a viable business model, and additional market research is needed. As the recycling container mainly uses imported machines, they may experience higher maintenance costs which will require higher profit margins from production. Developing a viable business model does not only secure revenue streams, but also be a tool to spread awareness by showing how plastics can be recycled and profitable.

5.4.2.2 Environmental Layer

Like with the project in Uganda, one of the intentions behind the project in Tanzania is to tackle the increased amounts of plastic waste by collecting and recycling plastics. A driver for developing a sustainable business model is therefore to attend to negative externalities caused by others. The development of the project's business model is based on producing new products from recycled plastics (Ingebo & Osborne, 2022). Like the project in Uganda, this will contribute to reducing plastic waste pollution and emissions from burning plastic waste. Other similarities are impacts from the product's end-of-life, as incorrect disposal can lead to pollution or emissions from burning. However, the products can be recycled again, supporting a circular economy.

As the project is yet to determine what products they seek to produce and what market to sell to, the environmental impact from the usage is hard to determine. As an example, targeting a global market will cause a greater environmental impact due to increased emissions from distribution and transportation. Some products may also require additional energy use during the use-phase. Other products, such as the intended rain gutters, could cause environmental benefits by collecting rainwater. As discussed in Chapter 5.3.2, the machines used in the recycling container are mainly imported, causing more emissions than those produced locally. The machines further require electricity and water for processing plastics. The energy source for running the machines is unknown, making it hard to estimate the emissions from production. Respondent S informed that the washing process consists of using buckets of water and a brush. Sand and sediments from the washing process are thrown into an existing pile of sand (Respondent S, 03.04.2023). As a result, any microplastics in the washing water or sediments will leak into the environment. The business model is still under development with many uncertainties, making it hard to assess the environmental impacts. However, depending on the volume of plastics recovered and recycled there is a potential that the environmental benefits will be greater than the impacts. An illustration of the environmental layer is shown in figure 22, Appendix P.

5.4.2.3 Social Layer

The project in Tanzania aims to create social value by creating jobs to reduce the rising unemployment rates, while reducing plastic pollution (Ingebo & Osborne, 2022). When a viable business model is developed and implemented this can result in social value on multiple levels. By creating jobs, the project can reduce poverty by providing income to unemployed citizens, which in turn strengthens the local economy. Collecting and recycling plastic waste contributes

to a cleaner environment with less emissions, and therefore improving quality of life. The end-users will experience benefits from a cleaner and safer environment, but additional social value for the end-user depends on what products the recycling station decides to produce. As the customer segment is undecided, it is hard to determine the scale of outreach. However, the project wants to engage the local community and spread awareness around plastic recycling and waste management (Respondent R, 03.04.2023). This could cause positive contributions to societal culture. See picture 23, Appendix P, for a representation of the social layer of the business model.

The employees of the recycling container are a specially trained station team (Ingebo & Osborne, 2022). These employees consist of local workers, but the respondents did not have any specific details about the workers (Respondent R and S, 03.04.2023). The plastic collectors will not be directly employed by the recycling container, but rather take a role as suppliers. As the recycling container wants to create value for the collectors they can be seen as stakeholders of the project. During the implementation phase of the technological solutions Respondent S talked to some waste pickers, where he noticed that they were quite difficult to talk to as he experienced some sort of skepticism (Respondent S, 03.04.2023). This aspect could be important to keep in mind to reduce potential conflicts arising between the different waste collectors. Formalization of informal waste collectors could be an approach to reduce the risk of conflicts. Like the project in Uganda, another potential social impact to keep in mind could be causing mistrust among citizens towards the municipality and their waste management services.

5.4.2.4 Relationship between the business model and technological solutions

Based on the data collected regarding the development process of the project's technological solutions and business model, it appears that the technological solutions have been the initial focus. However, the business model has not been excluded during this process as there was an idea of a potential business model behind the technological solutions. As discussed in Chapter 5.3.2, the students from NITO wanted to develop a solution that would recycle PET into filaments that could be used as filaments for 3D-printing, while other plastics could be recycled into new products (NITO, 2022). This indicates that the business aspect has been considered while developing the technological solutions, but that there is a lack of market research and testing to assess if the intended business model was viable and feasible. A downside due to the lack of a business model is that the recycling station is currently not producing, resulting in no revenue (Respondent R, 03.04.2023). The lack of revenue means that the project is unable to

create jobs as intended, and no plastics are recycled. This illustrates how technological solutions lose their value without a viable business model. However, an upside is that the machines have already been tested, and the project team has gained knowledge of what products they can make. If combining this knowledge with additional market research the project can be able to make a feasible business model that aligns with the technological solutions.

If assessing the three layers of the project's TLBMC, one can find multiple aspects that can help the project in the development process of a sustainable and viable business model. The economic layer has uncertainties in the value proposition, customer segments, customer relationships, and channels (Figure 21, Appendix P). These uncertainties directly impact the other layers in the model (Figures 22 and 26, Appendix P). As an example, as the project does not know what products they want to produce in their value proposition, the functional and social value for using that product is also unknown. When trying to determine these uncertainties the layers of the TLBMC can be a good tool for brainstorming.

To determine a value proposition, it is important to know who the project aims to create value for. A suggestive step is therefore to research the market to assess if there are any challenges or needs in specific customer segments that can be solved by offering a certain plastic product. For the project in Tanzania, this could for example be local tourist shops selling souvenirs looking for sustainable products to sell. In this process one should also evaluate the size of the customer segment and their willingness to pay to ensure that the project can secure sufficient revenue streams. If a marked demand is discovered, an idea could be to produce plastic figurines with local motives that can be sold to tourists. One can then assess if such a product can create a functional and social value. When assessing the environmental layer, a local market will cause less emissions than a global market due to shorter transportation distances. This illustrates how the project in Tanzania can use the TLBMC to move forward with business model development to find sustainable solutions that align with the project's economic, environmental, and social aims.

5.4.3 Bamako and San, Mali

As discussed in Chapter 5.2.3, the main intention behind the project in Mali was to create job opportunities in the informal sector by recycling plastic waste into school desks. To assess the feasibility of building a recycling station for school desk production in Bamako and San, a comprehensive study was performed. This study assessed various market factors, including whether there was a shortage of school desks, amounts of plastic waste needed for the school desk production, the technological solutions by Yamba D, in addition to performing economic

analysis to assess if the project could be financially viable (Zoure & Nonguierma, 2019). This indicates that the development of the project's business model heavily builds on the project's territoriality, ideation, and materiality. The proposed business model will be discussed through the three layers of the TLBMC (Appendix Q).

5.4.2.1 Economic Layer

Seen from the economic perspective one could argue that the project in Mali aims to create value for educational institutions as the business model is based on school desk production. Respondent U informs that Strømme Foundation often buy schools desks for their own education centers, and there has always been a need for desks as they often break. The feasibility study assessed the market for table benches and found that the Bamako district had a deficit of 48.274 benches spread over six communes. A market analysis for the facility in San estimated a need for 24.859 benches (Zoure & Nonguierma, 2019). The customer segment is therefore defined to be schools and other educational institutions. Respondent U informed that a goal was to create a market for plastic school desks, as an alternative to wooden school desks, and compete on a commercial basis with affordable prices and good quality (Respondent U, 09.05.2023). The economic layer is illustrated in figure 24, Appendix Q.

The value proposition that is offered by the recycling units in Bamako and San could therefore be to reduce pollution caused by plastic bags by recycling them into affordable and sustainable school desks. They aim to sell the desks to organizations that are responsible for their own procurement. The project had meetings with the Minister of Education and the Minister of Environment to promote sales. The municipal education sector has its own procurement portal where buy orders for desks and other school materials are posted (Respondent U, 09.05.2023). This procurement portal is therefore an important channel to reach the customer segment, in addition to advertisements in newspapers and commercials (Zoure & Nonguierma, 2019). This indicates that the business model offers automated services for their customers through the procurement portal, in addition to personal assistance when reaching out to other customers.

Key resources needed to deliver the value proposition are, like the other projects, the facility building, machines in the technological solution, plastic waste (LDPE), employees and knowledge. The employees are divided into two groups that perform different activities. The first group is responsible for collecting and sorting the plastics. The other group is responsible for melting and processing the plastics, and then assembling the finished school desks (Svendsen et al., 2019). Other key activities are related to commercialization. To secure a supply of raw materials (plastic waste) to the recycling units, plastic purchasing points were set

up in the main wild waste depots and markets of the Bamako district, in addition to purchasing points at unauthorized waste depots and main markets in San. These locations were selected as they constitute a potential supply of plastic waste. The managers of the purchasing points consist of women members of SFC. The women were encouraged to formalize themselves into a cooperative to ensure a link with the recycling unit. As a result, a women's cooperative was formed, which is now the main supplier of plastics to the facility (Zoure & Nonguierma, 2019). Other key partners of the recycling units are actors such as Yamba D, local workshops building the machines, EWB and the municipality.

The financial performance consists of revenue gained from sales of the school desks, and main costs which include gas usage, material costs, salaries, transportation, and maintenance costs. The feasibility study estimated the monthly operating costs to be F CFA 2.650.000. Based on a production of 200 school desks a month and a price of F CFA 35.000, the estimated sales income is F CFA 7.000.000. Based on these estimates the business plan is economically viable with a monthly profit of F CFA 4.350.000 (Zoure & Nonguierma, 2019). However, Respondent U informed that the recycling units have not been able to produce the estimated quantities. A total of 324 desks were produced in 2020, 991 in 2021, and 315 in 2022. Sales and distribution have shown to be a huge challenge due to the current conflict in Mali. As a result, the sales of desks have been low, and the recycling units are currently not producing. (Respondent U, 09.05.2023).

Respondent U confirms that the current business model has not been profitable and that the model needs to be revised. The conflict in Mali heavily influences sales as large amounts of resources are relocated from the educational sector to security. As a result, there have not been many requests to buy school desks through the procurement portal. Additionally, the costs have changed, and the project needs to reconsider if they need to reduce the number of employees in the production unit. Respondent U shared that market linkage is a challenge, and they see the need to produce products that are marketable. As there are no sales from public schools, the project is currently working on identifying private schools, potential clients and other organizations that provide education in various contexts to improve sales (Respondent U, 09.05.2023). If this is unsuccessful, other options need to be explored.

5.4.2.2 Environmental Layer

The project in Mali has a production target of 10 desks per day, where each desk requires around 30 kg of plastic. Based on these assumptions for the two recycling units, this would result in 600kg of plastic being recycled daily. Assuming 20 workdays per month, this equals to 12 tons

of recycled plastics. Seen from the environmental layer of the TLBMC this means that the facility has a functional value that can collect and recycle 12 tons of plastics on a monthly basis, in addition to the desks having a functional value when used in education, see Figure 34, Appendix Q (Yasien Ahmed et al., 2022). As plastic school desks are an alternative to wooden desks, this results in environmental benefits related to carbon sequestration and reducing decertification (Respondent U, 09.05.2023). Using the recycled desks would not require significant environmental impacts during the use phase, except for cleaning or potential repairs. The desks are made from plastic and metal, which are both recyclable materials when the product meets its end of life.

Environmental impacts from distribution consist of emissions from transportation, but the project is currently focusing on local markets to reduce transportation distances (Respondent U, 09.05.2023). The materials used in the school desk production are recovered plastics that contribute to reducing plastic pollution and emissions of black carbon. The production process itself does not utilize any hazardous chemicals, but the melting of plastics does generate waste and smoke (Zoure & Nonguierma, 2019). There is no emission control in the production process, but there has been an attempt to measure the composition of the exhaust gases from the melting process (Yasien Ahmed et al., 2022). Measuring quantities is challenging as the emissions are released into open air. Respondent U have informed that the project is working with local authorities like the Norwegian Pollution Control Board, and that the project is currently looking into production methods that are less polluting (Respondent U, 09.05.2023).

As a result, the project has the potential to recycle huge amounts of plastics which can create environmental benefits such as reducing plastic pollution and emissions, reducing desertification, and contributing to carbon sequestration by preserving trees that would otherwise be used in the production of wooden desks. However, as there is a lack of measurements on emissions from the different aspects of the business model, it is hard to determine the net impact caused by the recycling unit. Lastly, it is important to note that the project has not been able to meet its production targets, but this could be resolved in the future if the project is able to develop a viable business model. Currently a total of around 40 tons of plastics have been recycled during the lifespan of the recycling units (Respondent U, 09.05.2023).

5.4.2.3 Social Layer

Based on the current business model the project can create social by enhancing the quality of education by providing desks for a better learning environment, see Appendix Q. Additionally,

like the projects in Uganda and Tanzania, quality of life can be enhanced by reducing plastic pollution and related impacts. In turn, the end-users of the school desks can experience benefits due to a cleaner and safer environment, in addition to the comfort provided by working at a desk. The desks can be produced in various colors which can be aesthetically pleasing (Respondent U, 09.05.2023). The current scale of outreach is local, targeting schools. The outreach can have positive impacts as the recycling units provide training for actors in the value chain, in addition to improving learning environments for students. As previously mentioned, the project engages local actors in collecting and recovering plastics, and they have set up several collection points (Zoure & Nonguierma, 2019). This indicates that the project may carry a social agenda for developing a culture of responsibility in regards of plastic waste management.

During the interview with Respondent U, it was clear that the project has a focus on local actors and stakeholders (Respondent U, 09.05.2023). The business model has been developed by local partners in Mali, and the hired employees consist of vulnerable groups that receive training and an opportunity to join the workforce. The stakeholders have been engaged in decision making processes, and the goal is that the facilities should have local ownership that operates without future support from the project (Respondent U, 09.05.2023; Zoure & Nonguierma, 2019). Furthermore, the project has developed mutually beneficial relationships with actors in the local communities. The formalization of the women's cooperative was based on the Uniform Act for Cooperative Societies (OHADA), which ensures democratic decision-making and protection of the member's interests. It is estimated that the project will provide around 730 indirect job opportunities by setting up the purchasing points and engaging the women's cooperative in the project's supply chain. This is a significant contribution to local job creation that can aid in alleviating poverty. Lastly, the working conditions in the informal waste sector can be greatly improved if gender differences and inequalities are integrated. By mainly focusing on the women's cooperative, the project supports a shift from waste management as an extra chore for women to a source of income (Zoure & Nonguierma, 2019).

Based on this the operation of the recycling units in Bamako and San can lead to various social benefits. However, as plastic school desks are a direct competitor to wooden desks, this could reduce business for other producers and therefore impact the livelihoods of their employees. Like the projects in Uganda and Tanzania, there is also a risk of conflicts between plastic collectors and causing mistrust between the citizens and the municipalities.

5.4.2.4 Relationship between the business model and technological solutions

Respondent U informed that the initial focus in the Mali project was the technological solutions and production, but that he sees the need for a more simultaneous development of the business model: *"Firstly there is a focus on the technical, that we can [use] with production, and so, but really one need to have multiple thoughts in the head at the same time"* (Respondent U, 09.05.2023). However, as the technological solutions have been successfully implemented and tested, they have gained knowledge that is highly relevant for developing a viable business model: *"We see that it is possible to collect plastic, especially women's plastic, and create desks. We see that there is a challenge, that we must revise this business plan"* (Respondent U, 09.05.2023).

As discussed, the development of the current business plan is based on a feasibility study that found a market potential based on the bench deficits in the areas and economic analysis. Even though the analysis showed that the business model could be profitable, the project is still struggling with sales. This could indicate that the performed market research was insufficient as a deficit of benches does not necessarily mean that the customer segment has sufficient funds or willingness to pay. It is still clear that the development processes of both the technological solution and the business model have been heavily influenced by the four dimensions of the analytical framework. Even with the modifications needed in the business model the project has still been able to implement a technological solution that was fit for local conditions, while confirming the suitability for plastic waste collection and school desk production, which aligns with the intended business model.

Through the discussion of the project's economic, environmental, and social layers, one can see that the economic layer of the business model is the biggest challenge. When revising the current business model, the TLBMC can be a useful tool to ensure that any changes made in the economic layer will not cause major negative impacts on the value creation across the other layers. The project is currently trying to identify new customers to increase sales, but they are looking into expanding to other areas in Mali and Sikasso (Respondent U, 09.05.2023). The expansion of the customer segment could result in more sales, but market research is needed to assess the demand and willingness to pay. If the project is unable to increase sales within the current customer segment, they can look at other aspects of the business model.

As the project already has a functional production unit, a suggestive solution could be to consider production of similar products that can be offered to a different customer segment. One idea could be to assess the market demand for restaurant tables or other products that can

be produced with the existing machinery. This modification would not cause intrusive changes to the other aspects of the business model, but it will affect the functional and social value offered in the other layers of the TLBMC. The project would still be able to reduce pollution and emissions through plastic waste recycling, but it will no longer create value for educational institutions. As the production method is the same, there are no additional emissions from offering tables rather than desks. Additionally, the project would still be able to create both direct and indirect jobs which benefits the community.

Furthermore, Respondent U informs that the project plans to increase collaborations with the private sector to build competence and networks. Another consideration is to increase their work with advocacy to influence attitudes and decision making in plastic waste management. An important question related to this is whether the project should create jobs within the plastic waste management sector, or work towards banning plastics (Respondent U, 09.05.2023). This illustrates how the other layers of the TLBMC can be used to assess how the shift of approach affects all value creation aspects of the project. As an example, working with advocacy can still result in reducing plastic waste pollution which will benefit both the environment and communities. However, the project will no longer create jobs that can provide vulnerable groups with income, which can reduce social benefits. This would require a complete shift in the economic layer of the business model if the project were meant to be profitable. Such a shift would therefore not be in line with the project's intentions of creating jobs. An alternative could therefore be to find a way to integrate advocacy work into the current business model. This can for example be done through earmarking profits earned by the recycling units for advocacy work, or by increasing the involvement and collaboration with governmental actors.

To summarize, the project the technological solutions that are implemented align with the intended business model and project intentions, but changes are needed to ensure long-term sustainability and profitability. The TLBMC can be a helpful tool in the future development process of the business model as it illustrates how a change in one aspect affects other parts of the business model. Future suggestions could be to perform additional market research to explore new product offerings and customer segments.

5.4.4 Discussion of Business Model Generation

During this chapter, we have seen different approaches to the development of the project's business models. While the project in Uganda developed a business model alongside with the development of the technological solutions, the projects in Tanzania and Mali had the initial focus on technology development before developing a business model. The project in Uganda

has developed a business model based on market needs and a complete supply chain has been established. However, the facility is not yet operational as there are some technical challenges that need to be addressed. Both the projects in Tanzania and Mali have implemented working technological solutions, but none of the recycling facilities are currently operational due to a lack of a viable business model.

The early focus on business model development can be a distinguishing factor between the project in Uganda and the projects in Tanzania and Mali. Measures for managing the technological challenges met by the project in Uganda are in progress. As a result, the facility in Uganda can start production once the challenges have been resolved, reducing the downtime of the facility. In a contrast, the recycling container in Tanzania has not been in production the last year, and the recycling units in Mali had low to no production. Both are currently looking to revise their business model, but the timeframe for finding a viable and profitable solution is uncertain (Respondent R, 03.04.2023; Respondent U, 09.05.2023). This illustrates how the lack of viable business models can remove the value of a functional technological solution as there cannot be any production without customers and sales. This results in a lack of revenue that could have been used to create value for customers and stakeholders.

While all the projects have implemented solutions that are influenced by the territorial, discourse, materiality, and organizational dimension of the analytical framework, the degree of iterative integration has varied between the projects. The main difference can be found in mapping the projects territoriality. Both the projects in Uganda and Mali performed thorough preliminary assessments to explore the local structures and feasibility. The project in Tanzania did not have sufficient time to perform preliminary work, which has been recognized to be one of the main challenges of the project (Respondent R, 03.04.2023). Without sufficient insight into the local market and actors it is challenging to assess the potential market challenges or needs that can be resolved by the project. This indicates that mapping a project's territoriality is a crucial aspect of innovation projects, as it is hard to create value without knowledge about potential customers and stakeholders.

Further, this chapter has discussed how the Triple Layer Business Model Canvas can be used as a tool when developing sustainable business models and brainstorming new ideas. The TLBMC takes a holistic approach that illustrates how a project can create economic value while considering any environmental and societal impacts caused by the decisions made in different aspects of the model. As an example, if the aim is to set up a business with low carbon impact, the environmental layer can be used to assess any emissions and impacts caused by production

methods and distribution channels. If the results are not satisfactory one could go back to the economic layer to assess other potential solutions that are less polluting. This illustrates how the multidimensionality of the analytical framework for plastic waste management innovation can design the implemented solutions. Implementing a technological solution through a sustainable business model requires contextual knowledge, utilizing this knowledge in accordance with project intentions, and assessing how decisions affect the different aspects and layers of the business model. Additionally, the business model is dependent on a functional technological solution to perform its key activities. In the same way, the technological solution depends on a viable business model to create its intended value, where contextual knowledge and well-informed decision-making are essential to ensure that the technology is suitable for local conditions. Additionally, environments and circumstances around a project may change, creating a need to revise a business model. Businesses should also frequently explore ideas and new opportunities for improving and scaling their business to ensure long-term viability.

In conclusion, one can argue that business model generation is equally essential as developing a technological solution that fits local conditions. Without a viable business model, technological solutions can lose their value as there are no economic incentives for starting production. All dimensions of the analytical framework are essential in business model development as the various dimensions influence different aspects of the business model. Sufficient market research through the project's territoriality seems to be especially crucial as it helps to identify business opportunities that can ensure a good fit between the implemented technology, business model and market conditions. To avoid downtime and secure revenue streams, it can therefore be recommended that future projects iteratively assess how the four dimensions interact with each other during the development process of both technological and business solutions.

5.5 Final Discussion

During this research we have analyzed the recycling projects in Uganda, Tanzania, and Mali through a framework consisting of four dimensions for plastic waste management innovation and assessed whether they fulfill the criteria being considered responsible innovation projects based on their implemented technological solutions and business models. The analysis discovered several patterns across the four dimensions, territoriality, discourse, materiality, and organization.

From the three projects' territoriality, Uganda, Tanzania, and Mali all had an extensive issue with plastic pollution. The main pollutants across all cases seemed to be PET and LDPE. The waste management systems in all countries were insufficient, which combined with a lack of awareness around plastic waste recycling led to environmental pollution and poor waste management practices. For the cases in Uganda and Mali openly burning plastics and disposal at unofficial dumpsites seemed to be common practice, while the case in Tanzania did not reveal specific information on the current practices. Furthermore, for the plastics that get recycled, findings indicate that the informal sector is a key contributor. There are existing structures of various types of plastic waste collectors and intermediaries that collect, sell, and recycle plastic waste, driven by economic incentives. The case from Uganda revealed that HDPE and PP were the main collected plastics. PET was considered unprofitable due to low margins, while there were already structures for PET management in Tanzania and Mali. The case in Mali also revealed structures where higher quality plastics, such as HDPE, are used for material valorization, while lower grade plastics are used for producing paving stones. These findings indicate that the plastic types that get collected are based on the ability to add monetary value through processing, where HDPE is often seen as a higher quality plastic with increased profit potential. Lastly, the main challenges discovered from the projects' territoriality were low profit margins, poor access to capital, and poor quality of equipment. The projects had various degrees of preliminary work, and only the project in Uganda explored prices and costs within the informal sector.

From the discourse dimension, all cases had similar intentions of reducing plastic waste pollution and creating job opportunities. The case from Uganda emphasized that the project should be based on a local context where the implemented solutions should be suitable for local conditions, while working in harmony with current structures. Similarly, the project in Mali saw the importance of using local competence and focused on collaboration with local actors with both the selection of technological solutions and business model development. In contrast, the project in Tanzania did not include the same local focus. Additionally, only the projects in Uganda and Mali have municipal involvement. All projects aim to create value across all layers of the TBL, which is an important factor to be considered sustainable and responsible. Findings indicate that the discourse dimension is an important tool in decision-making processes. This can be elucidated by the SUWASO case. Based on knowledge gained from the local context and intentions behind the project, the discourse dimension became an important factor in discussing potential solutions during the development processes, and thus guiding the final

solution to align with local conditions, and the project's aims, intentions, and other ethical criteria.

In the materiality dimension the projects took different approaches to technology development. One factor that was repeated among all the cases was limited access to tools and resources. As a response to the challenge of resource scarcity, the project in Uganda designed a low complexity shredder, where simple production methods and resource availability were considered. The project in Mali based its implemented technology on an existing solution that was produced locally. The implemented solutions in the project in Tanzania were imported but assembled locally. Availability of local resources became a challenge when this project met technical issues, as it was hard to find spare parts that eventually had to be ordered from Norway. As territoriality has revealed that access to capital is a common issue amongst actors in the informal waste sector, this could result in a risk of the machines being left to rust if it is not feasible to fix them with locally available resources. These findings indicate that focusing on a local context is an essential factor in developing sustainable waste management systems, which also can contribute to increasing local competence and resource utilization.

When assessing the projects' organizational dimension, the degree of business model development varied between the three cases. One of the main differences was the degree of market research performed. Both the project in Uganda and Mali researched market opportunities, which became the fundament for developing a business model. Both projects have developed a complete business model with the potential to create value across all the layers of the triple bottom line. Still, the project in Uganda needs additional testing to verify the profitability of the business model as the technological challenges need to be addressed. The shredder needs additional testing to determine the expected production rate of shredded plastics, which can have a huge impact on the business model's profitability. Similarly, the project in Mali needs to revise its business model due to low sales in the intended customer segment. The project in Tanzania has yet to develop a viable business model, and market research is recommended to find a profitable product and customer segment. These findings suggest that business model development is highly dependent on the degree of market research performed. Additionally, since the implemented technological solutions are essential to perform the business' key activities, the materiality dimension suggests that these should be adapted to local conditions to ensure long-term and sustainable solutions.

While it is evident that all the projects aim to create value across the TBL, none have currently been successful in starting a profitable production. It is important to note that none of the

projects are complete, and all are working on making the changes that are necessary to overcome their challenges. Long-term results are needed to decide whether they are creating value across the TBL according to their intentions. If able to overcome their challenges and implement sustainable and profitable business models, all projects can be considered responsible innovation projects based on the analytical framework.

Further, the framework for plastic waste management innovation is meant to assess whether a project can be considered responsible, but it has also shown itself to be a good tool for the development processes of both technological solutions and business models. While each dimension can be helpful in assessing different aspects and variables of a project, it is their collective contribution that can aid plastic recycling innovation projects in creating a holistic and sustainable solution. Mapping the territoriality of a project is a good starting point for assessing essential market conditions. While a project's intentions tend to be set, one will tend to gain new knowledge through the various development processes. This enriches both the project's territoriality and discourse dimension and becomes an important factor in the decision making related to development of both the technological solution and business model. Further, both the materiality and organizational dimension are interrelated. The business model depends on a functional technological solution to deliver its intended value proposition, while the technological solution will lose its value if not paired with a viable and profitable business model. Assessing all the dimensions of the framework during the various development processes can enable the development of solutions that fulfil the criteria of being considered responsible, while ensuring coherence between the different aspects of the project. As a result, the success for implementing a holistic, sustainable, and long-term waste management solution that is adapted to local conditions. In turn, this can encourage actors to engage in waste management practices, increasing efficiency and resource utilization as plastic waste can be considered a resource.

6.0 Conclusion

The aim for this research was to map different patterns connected to developing more effective and sustainable systems for plastic recycling in rural African areas, which can be used as a "best practice" for similar and future projects. By discussing the three cases through the analytical framework for plastic waste management innovation, I have discovered several conditions that can contribute to a project's success. This research sought to answer the following research

question: *How can business model innovation and technology adaptation increase the viability of plastic recycling in the informal waste sector in rural Africa?*

I organized my discussion based on four dimensions from the framework for plastic waste management innovation, territoriality, discourse, materiality, and organization (figure 4). This framework was based on the responsible innovation complex (figure 3). From the main case, the SUWASO project, there are two main factors that have contributed to the project's progress and potential to implement a profitable recycling facility. The first factor is the project's contextual knowledge. The project spent a field trip to gain knowledge of the current practices, prices, and perspectives within the informal waste sector in Mityana, assessing resource availability, to align first-hand observations with the findings in a baseline study that was performed by the local partner, REDS. The amount of time that was dedicated to preliminary work has proven to be beneficial as it has heavily influenced decision making and further development processes. This factor can be understood as knowledge of the territoriality aspect from my model (figure 4).

The second factor is related to the discourse dimension and intentions behind the project, which was to have a local focus with collaboration and harmony with existing structures. While the first factor has enabled sufficient contextual knowledge to keep a local focus, the second factor has ensured that this knowledge was utilized in the decision making during the development processes. As a result, the project was able to respond to challenges by using contextual knowledge and limited resource availability as a strength, designing new technological solutions that utilized local competence, materials, tools, and collaboration between actors. This solution was developed in line with accordance with a potential business model that was based on the contextual knowledge gained from actors in the informal waste sector. This enabled the project to calculate a more realistic financial picture, rather than pure assumptions. It is likely that this is a contributing factor to ensure that the implementation of the complete solution is profitable and suitable for local conditions. As previously discussed, the business model is not yet implemented, and results are needed. However, the challenges met have been manageable as collaboration between actors and resources needed has been established locally. These findings indicate that the combination of gaining sufficient contextual knowledge, utilizing this knowledge in discourse and decision making, and therefore developing technology and business models that are adapted to the local conditions, can improve the project's potential for success.

These findings have been additionally informed by the findings from the supplementary cases. To elucidate this, the project in Mali did gain contextual knowledge through a feasibility study and local partners in Mali. This knowledge was further utilized in discourse around the technological solutions by Yamba D, in addition to business model development. The technological solution was developed and built locally, and the project did not experience any issues or lack of research during implementation. The business model was also developed based on the implemented technological solution and the discovered deficit for school benches. Even though the project in Mali is currently struggling with profitability due to poor sales, the findings from the analysis of this case shows that contextual knowledge and a local focus has played an important role in their development processes.

The project in Tanzania did not gain the same contextual knowledge compared to the other cases, due to insufficient time. Further, from the data collected there was not discovered any intentions of a local focus. This indicates that the project did not utilize the same degree of contextual knowledge in their decision making and development processes compared to the other cases. As a result, they met challenges when they initially did not operate as intended, and necessary spare parts and tools could not be sourced locally. The findings from the analysis indicated that the lack of contextual knowledge may have affected their ability to develop a viable business model as they have not yet uncovered a concrete need in the local market. However, this does not mean that the project will not achieve success, but rather illustrates how contextual knowledge could have reduced some of the challenges experienced. Furthermore, the challenges faced by the project can give valuable insights as these are contributing to gaining contextual knowledge. It is also important to note that the project has been successful in implementing a functional technological solution that has the potential to produce a range of products. In turn, this illustrates how the project can use the analytical framework to move forwards with their development processes, where gaining knowledge through market research can create the insight needed to develop a viable and profitable business model.

To answer my research question, it is better to first answer my partial research question, *"How can adaptation of technology to local conditions create value along the triple bottom line?"*. The findings from this research indicate that adapting technological solutions to local conditions can result in multiple benefits. Firstly, when focusing on the local context one can ensure that the technological solution can create value for the actors in the waste sector, the environment, and tend to a local challenge or need. Secondly, focusing on local production methods and resource availability contributes to ensure that the machines become a long-term solution as

they can be maintained and repaired locally. Findings from the SUWASO case suggest that technology adapted to local conditions might be more cost effective to produce, reducing the need for capital within the informal waste sector. As competence, knowledge, and resources are secured locally, this enables additional production of machines for scalability. Thirdly, a technological solution that is suitable for local conditions can increase the efficiency for plastic waste recycling, and thus increase margins for collecting and selling plastics. As a conclusion, adapting technology to local conditions can create economic value by increasing efficiency of plastic waste management, which results in environmental benefits by reducing plastic pollution, which in turn can enhance quality of life for citizens and stakeholders.

The second partial research was *"How can sustainable business model development contribute to responsible implementation of plastic recycling technologies in rural Africa?".* This can be seen in the light of the previous research question as the technological solution must be paired with a viable and profitable business model to create value. For a business model to be considered sustainable, it needs to create value on an economic, environmental, and social layer. By combining the four dimensions of the analytical framework for plastic waste management innovation during the development process one can ensure that the implemented solutions are suitable for local conditions, work in harmony with current practices, while creating value on all three layers. In this context it is important to note that it is not each dimension alone that contributes to developing responsible waste management solutions, but rather the multidimensionality of the model. As a conclusion, when implementing a technological solution that is adapted to local conditions through a sustainable business model, this fulfils the criteria for being considered responsible. This illustrates how the development of sustainable business models can contribute to the implementation of a responsible implementation of plastic recycling technologies in rural Africa.

Finally, based on these insights, one can conclude that sustainable business model innovation and technology adaptation is likely to increase the viability of plastic recycling in the informal waste sector in rural Africa by providing technology that increases the efficiency of plastic waste management. This in turn is likely to increase the margins for collecting and selling plastics within the informal waste sector. By showing how plastic waste recycling can be profitable through sustainable business models this can encourage additional actors to engage with plastic waste management, thus further encouraging efforts to tackle the highly critical issue of plastic pollution.

7.0 Further Research

A shortcoming of this research was that none of the projects that were analyzed were completed, and therefore lacked long-term results. In further research it would therefore be beneficial to assess the long-term results and profitability and sustainability of the three projects. This could reveal potential success factors and challenges that can be used to further explore how to successfully implement sustainable waste management technologies in rural Africa. Additionally, it would be interesting to analyze a larger selection of projects to gain a better understanding of their development processes, challenges, success factors, and results. I think these findings could be beneficial for improvement of the framework for plastic waste management innovation, which again may create value for future projects and its stakeholders.

Furthermore, there were multiple aspects that could have been relevant for my results, which could not be included in my analysis, due to time- and resource limitations. One aspect that would have been beneficial to assess is circular economy principles and how this could affect plastic waste management within the informal waste sector, in addition to socio-economic and societal impacts. Lastly, while this research explored how projects can develop solutions to manage and recycle plastic waste, it did not concern advocacy and awareness campaigns.

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9.0 Appendices

Appendix A – Plastic Waste Statistics and Projections

There seems to be a consensus amongst researchers that the plastic pollution issue is an urgent matter that presses the current waste management systems in African cities (Aryampa et al., 2019; Ayeleru et al., 2020; Babayemi et al., 2019; Godfrey, 2019). A report on municipal solid waste (MSW) generation by the United Nations (UN) shows that around 99% of bought consumer goods end up as waste after the first six months of acquisition. This is considered one of the major factors that are driving the amount of solid waste (SW) generated yearly across the globe, where huge parts of this MSW consist of plastic waste (Ayeleru et al., 2020; Wahlén, 2018). Research has shown that waste composition correlates with income, and for low- and middle-low-income levels, the fraction of plastic is estimated to be between 6,4%-11% (Kaza et al., 2018). For African counties, the waste composition is estimated to consist of around 57% organic waste, 13% plastics, 9% paper, 4% metal, 4% glass, and 13% of other waste (Hoornweg & Bhada-Tata, 2012)

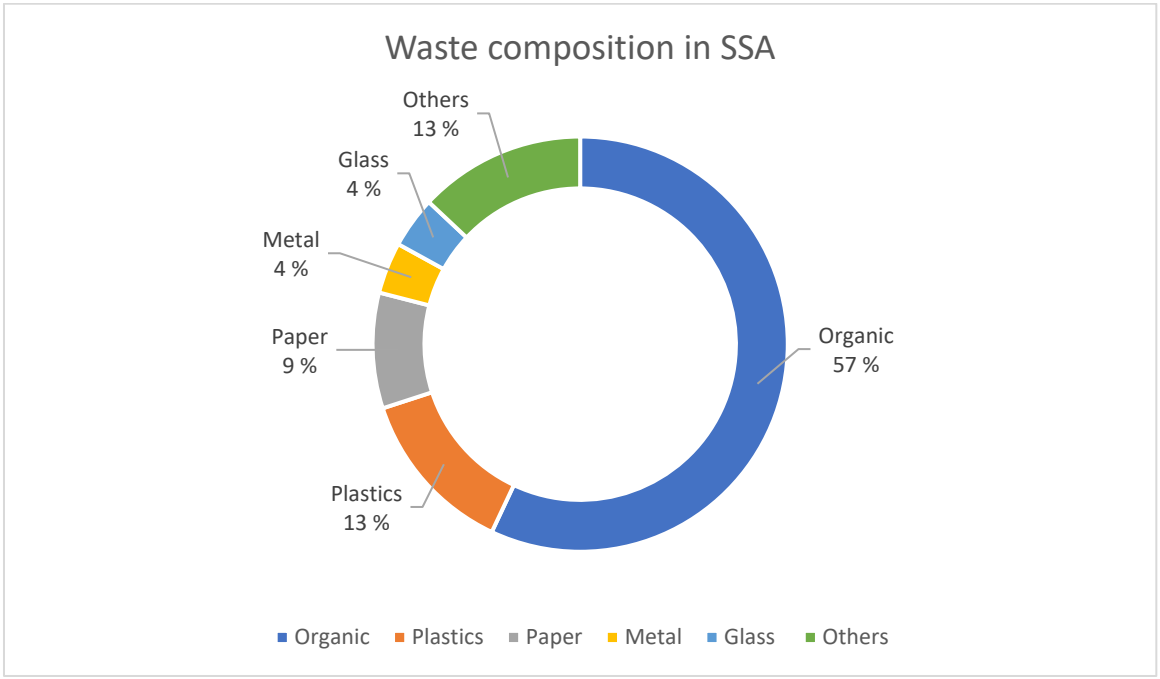


Figure 6 - Waste Composition in SSA (Hoornweg & Bhada-Tata, 2012)

Research conducted in Sub-Sahara Africa (SSA) reveals a 55 million ton increase from 2012 to 2019, projected to reach 244 million tons by 2025 (Debrah et al., 2022). Waste generation in the East African Community (EAC), is expected to rise with 60-70% by 2030 in cities like Kampala and Dar es Salaam. This increase will result in negative impacts on already inadequate waste management systems (Aryampa et al., 2019; Okot-Okumu, 2019). Researchers have

found a correlation indicating that a 1% increase in population growth will cause a 0,9% increase in waste generation. Other factors that affects waste generation are urbanization, economic growth, income per capita, and overall industrialization (Hoornweg et al., 2015). Households in SSA are generally poor, and due to the high rates of population growth and urbanization, there is a limited economic influence on waste generation in some African countries. Based on the increase in waste generation, Aryampa et al. (2019) highlight the need for careful Urban planning to avoid waste growing to levels that render cities inhabitable. With the projections given, there is a need to develop more sustainable waste management systems.

Appendix B – The Plastic Life Cycle

One of the biggest sources of plastic pollution originates from the plastic packaging sector and synthetic textiles. This can be illustrated through the African plastic life cycle, which is divided into five distinct stages, see figure 7. As of today, the plastic life cycle in Africa is not a closed loop, and huge quantities of plastics leak into the environment due to system failures in every stage, see figure 8 (Sadan & De Kock, 2021). Common plastic products that contribute to the environmental pollution in Africa include PET bottles, other non-drinking bottles, plastic bags, disposable nappies, and lids and caps. Plastic bags are an issue in most countries across the continent as they are mostly single-use and get discarded quickly (UNEP, 2018). The improper disposal of these products results in adverse effects on human health, socio-economic factors, infrastructure, ecosystems, and climate change (Sadan & De Kock, 2021). The plastic leakage results in the release of microplastics into the environment, which can contaminate sources for drinking water, fruits, and vegetables. Research suggests that an individual might consume up to 5g of microplastics every week (Senathirajah et al., 2021). Additives such as persistent organic pollutants (POPs), have been found in chicken eggs due to the current plastic management in developing countries. These additives can also be found in other products, such as children's toys. Exposure to these additives is associated with negative impacts on the endocrine, immune, and reproductive systems (Petrlik et al., 2021)

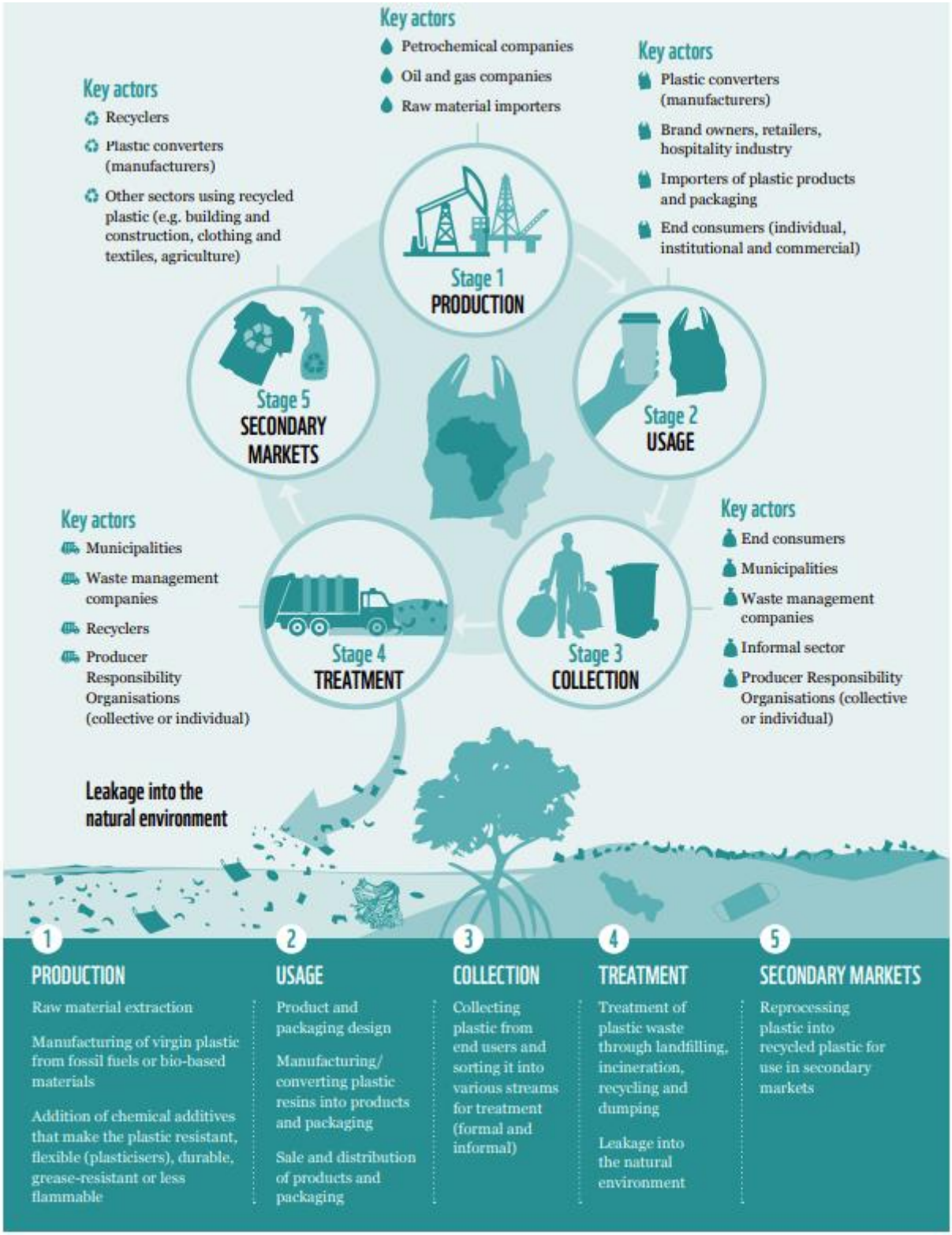


Figure 7 - The Plastic Life Cycle (Sadan & De Kock, 2021)

Figure 8 - System Failures in the Plastic Life Cycle (Sadan & De Kock, 2021)

Appendix C - Interview Guide for EWB Projects

Introduction

Inform about myself and my study program. Present the SUWASO project and its aim.

Inform respondent about documentation of the interview and personal data.

Ask for permission to record

Background

- When the project started, what was the current state in Dar es Salaam?
    - What was the amount of waste?
    - What kinds of plastics?
    - How aware were people on plastic waste management?
- What was the practice behind plastic waste management/waste management when the project started?
    - What sectors were involved?
        - Formal sector/private?
        - Informal sector?
    - What was the process behind plastic recycling? (Sorting, collection, transport, recycling, sales, etc.)
- What were the biggest drivers for plastic waste or waste management?
- What were the main challenges to the different actors related to plastic waste management?
    - Transportation costs or other costs?
    - Access to equipment or tools?
    - Access to capital?
- Were there any cultural aspects you became aware of?
    - E.g., trust, relationships, daily routines etc.

Ethics/discourse

- What were the intentions behind the project?
- Can you tell me a little bit more about the ideation phase of the project?
- Were there any ethical guidelines that were particularly emphasized?
    - E.g., socially, or environmentally?
    - Local communities?
    - Workplaces?
- Related to development of technology, were the implemented machines developed by the project or bought?
    - Where were the machines bought/developed?
    - Can you elaborate on why?
- Were there any factors related to HSE?
- Any other aspects such as attitudes, language, or cultural differences that were considered, challenging or experienced?

Materiality/technology

- Can you tell me about the development of the project's technological solutions?
    - What needs were the solutions supposed to cover?
    - Development of machines and innovation processes?

    - Who participated in the development process?
        - Inclusion of local actors or co-creation?
- What resources were available locally?
    - Materials, electricity, tools, knowledge, competence, etc.
- How did the implementation of the solutions work?
    - Who participated?
    - Who is responsible for daily operations and follow-ups?
- Did you face any challenges related to the development of technological solutions?
    - How were they handled or solved?
    - What could have been handled differently and why?

Organization

- Can you tell me about the development of the project's business model or business case?
    - What does the model include?
        - Cost structures, revenue streams, partners, employees, resources, customers etc.?
- How did the development process work?
    - Can you elaborate why things were done this way?
- Who were the project's/business model's stakeholders?
- Any collaboration with the government or other actors?
    - In what degree?
- How was the daily operation of the facility organized?
    - Structure, employees etc.?
- If there were any informal actors involved, do you know if these were organized in any way?
    - If yes, can you elaborate?

Appendix D – Additional Information on the Territoriality in Uganda

Current State of the Plastic Waste Problem

Mityana municipality is in the central region of Uganda and has a population of around 100 000 people, which makes up approximately 24.042 households. The municipality is divided into 3 divisions, Central, Ttamu, and Busimbi, where each division has its own political leadership. Plastic waste is a huge problem in the municipality and conversations with the Town Clerk and the Natural Resource department have revealed that around 15 tons of garbage, including plastic waste, are generated every day. The composition and waste fractions are unknown by the municipality (REDS, 2021).

From the baseline study performed by REDS, respondents reported that Polyethylene bags (LDPE) and plastic bottles (PET) were the most generated plastic waste. Other types of plastic that were reported by the respondents were broken jerrycans, basins, buckets, plastic containers, utensils, and food containers, which generally is made of high-density polyethylene (HDPE) (REDS, 2021). A composition of the plastic waste generated by households in Mityana is shown in figure 9.

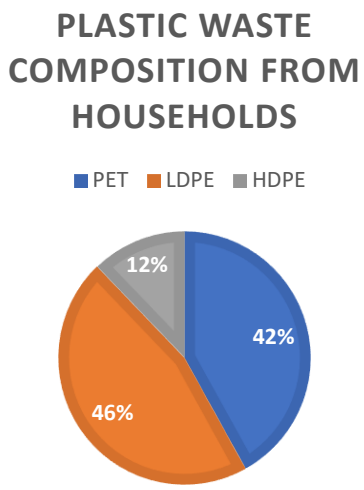


Figure 9 - Plastic Waste Composition from Households in Mityana (REDS, 2021)

During the first field trip to Mityana it was seen that LDPE plastic bags were one of the main sources of pollution. However, LDPE is not a highly recyclable plastic as it is often contaminated and of inadequate quality. This makes the recycling process hard and not economically viable. Another main source of plastic pollution that was seen is PET bottles, which is easier to recycle and there for has a better potential for creating new business models (Langseth, 2022). Further information from the baseline survey revealed that almost every

household produces daily plastic waste in the form of PET bottles. A small fraction of respondents, 13%, reported that they do not produce PET bottles daily. The biggest plastic waste producers were institutions, hotels, guest houses, restaurants, and shops, where 47% reported a production of >5 bottles every day. Other types of households generated on average 2,4 bottles, see figure 10 (REDS, 2021). There are approximately 45 PET bottles in one kilogram and based on the number of 24.042 households in the municipality, this results in an estimated production of 57.700 bottles or 1.282kg every single day (REDS, 2021). Hence, in one month this results in an estimated production of 38 tons of plastic bottles alone.

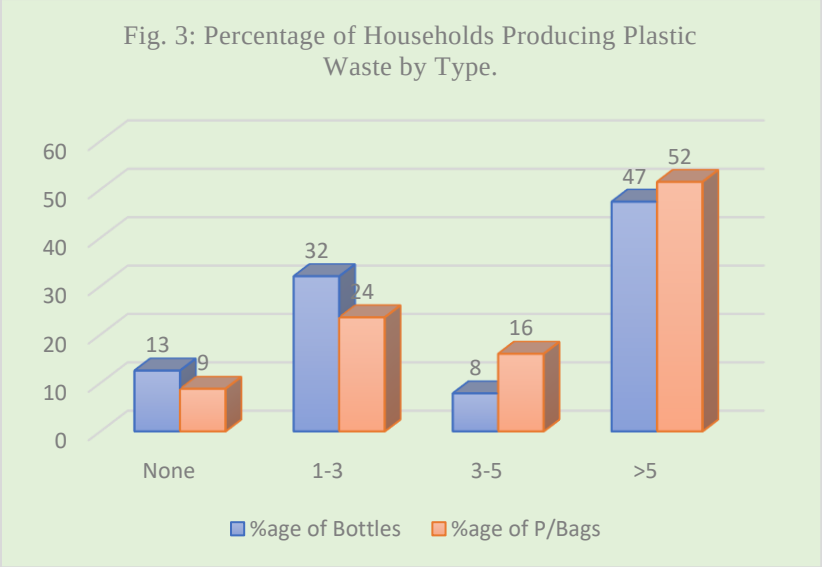


Figure 10 – Percentage of Households Producing Waste, by type (REDS, 2021)

It was clear that waste management is a huge problem in the municipality. 60% of local revenue that is collected monthly is used on garbage collection and transportation to the landfill. This revenue is originally earmarked for other activities. Collected waste is transported to a landfill in Namukozi in the Central Division. The landfill area covers 8 acres and is split into two divisions; one for garbage and one used as a burial ground for unclaimed human bodies. The landfill area is small and is currently almost full of unbiodegradable waste, mainly plastic and rubber. The municipality is in a need for an additional landfill in the Ttamu division to reduce distance and thus reduce transportation costs (Langseth, 2022; REDS, 2021).

Picture 3 - Plastic Waste on the Landfill in Namukozi (Langseth, 2022)

Other observations done during the first field trip to Mityana in March 2022 confirmed the plastic waste problem. Several types of plastics, mostly bottles and bags, were found in most streets. There were no visible trash bins or sorting stations around the town, except for a couple of bins at Mityana Hospital. In multiple locations there were also larger accumulations of plastic waste, creating unofficial dumping spots. At most times there was also a distinct smell in the air. This smell was due to plastics regularly being burnt at various locations (Langseth, 2022). This does not only cause air pollution, but the baseline study performed by REDS discovered that some households utilized plastic waste for cooking food which causes toxic emissions hazardous for human health (REDS, 2021).

Picture 4 – Street Littered with Plastics (Langseth, 2022)

Picture 5 – Accumulation of Plastic Waste (Langseth, 2022)

On multiple occasions people were seen casually dropping their waste on the street, showing that awareness around plastic waste management is low. This was confirmed by multiple actors in Mityana (Langseth, 2022). One of these actors was Respondent Group J, which consisted of the leaders in a plastic waste cooperative. They informed us that there is a lack of awareness in the community as many are not aware of plastic recycling (Respondent Group J, 02.04.2022). One of the vendors on the main market in Mityana, Respondent L, also mentioned awareness as an issue, especially related to sorting: "*many can't even differentiate plastics from metal*" (Respondent L, 04.04.2022). It was emphasized that this is due to both lack of training and attitudes towards plastic waste management and recycling.

Current Practices

The current practices in Mityana were mainly mapped by talking to the different actors in the plastic waste sector. The plastic waste sector on Mityana consists of both formal and informal services, and during the first field trip we mainly spoke to actors in the informal sector. Firstly, both the baseline study performed by REDS (2021) and interviews with Respondent C, K, L, and M revealed that waste usually does not get sorted. At the main market in Mityana there is no system for sorting waste and all garbage is collected in the same bin before it gets transported to the landfill (Langseth, 2022). Respondent C informed that community center gave away their plastic waste for free if plastic waste collectors came by. If the plastic waste is not given away it gets burnt together with the remaining general waste (Respondent C, 01.04.2022). Respondent M, Mityana Secondary School, informed that they only sorted out glass waste as this could be hazardous (Respondent M, 04.04.2022). Other households often store unsorted garbage in gunny bags that later will be picked up by a municipal truck (REDS, 2021).

The municipality only has one truck that is unable to do daily rounds for collection. Due to this the truck only covers areas that are close to the main roads in the municipality. The neighboring areas can bring their garbage to the truck as it honks when it arrives, but it does not always stay for a long period of time. There are no specific collection days for the different areas, and the collection rate varies from 2-3 days a week to once every two weeks. Certain areas are not covered by the municipal garbage collection at all, which leads to alternative methods for garbage disposal. The main alternative methods for garbage disposal are through plastic collectors or by burning. Some households also reported that they store their waste outside their house, leave it on the roadside, or buries it underground. 33% of the respondents informed that

they use their plastic waste, mainly LPDE bags, as fuel for their charcoal stoves as there they have little firewood available for cooking food. Most of these respondents seemed unaware of the dangers this causes to both their health and the environment (REDS, 2021).

The informal sector in Mityana consists of plastic waste business collectors, *PWBC*, that buy plastic waste from the households in the municipality. Around 20 collectors have their own stores for different kinds of scrap, mainly metal and plastics (Langseth, 2022; REDS, 2021). Several PWBCs in Mityana have come together to form a cooperative with a main goal to increase working capital and efficiency. This cooperative was registered in October 2020 and consists of around 150 PWBCs. However, only around 60 PWBCs are active and attend meetings (REDS, 2021). During the first field trip 6 PWBCs were interviewed, Respondents D, E, F, G, H, and I. The respondents informed that they employ workers that drive around on motorcycles or bicycles to collect plastic waste from households. Some workers are provided with a megaphone to announce their arrival and what types of scrap they are looking to buy. Each worker is provided with capital to buy plastics, before it gets transported back to the plastic waste business collectors, weighed, and sorted. The plastics are then sold to recyclers in neighboring districts and Kampala. Some PWBCs manually cut the plastics into smaller pieces to increase the plastic load per truck. The average load per truck was around 4 tons of plastics (Langseth, 2022).

Picture 6 and 7 – Storage of Collected Plastics at PWBC (Langseth, 2022)

The average load per motorcycle depends on what kinds of plastics are collected, but Respondent D estimates around 60kgs per run (Respondent D, 02.04.2022). From the baseline study the average amount for collected plastics per PWBC is estimated to be 220kg (REDS, 2021). Most respondents collected HDPE and PP as these have the best margins. All respondents, except for Respondent H, did not collect PET-bottles as the price points were too low, making it unprofitable (Langseth, 2022). Respondent H confirms that the price point for PET-bottles is low, but that he has several buyers that collect the bottles from him. For the bottles to be profitable he needs to get a decent price, but the prices fluctuate from month to month (Respondent H, 02.04.2022).

Drivers and Challenges

When assessing the drivers for plastic waste management in Mityana, one important driver is economic incentives. Discussions with REDS and Respondents D-J, O, and Q have confirmed that there is a current market for recycled plastics, resulting in possibilities for creating informal jobs and economic value (Langseth, 2022). The PWBCs, Respondents D-J, sells their plastics to recyclers such as Respondent O and Q. Respondent O proceeds to sell some of their plastic to Nice House f Plastics or other customers in the US, Vietnam, and South Africa. Respondent Q sells creates and sells preformed plastics to bigger vendors such as Pepsi (Langseth, 2022). One challenge that was repeated among the PWBCs was price fluctuations. The margins can vary from month to month, and average buying and selling prices for the PWBCs is summarized in table 2 (REDS, 2021).

Plastic waste type	**(N)**	**Average buying price (UGX)**	**(N)**	**Mean selling price (UGX)**
PET bottles	1	150	1	550
Jerricans (HDPE)	10	1090	8	1700
Basins/buckets (PP)	10	530	8	812
LDPE bags	4	450	2	850
Worn utensils (PP)	3	450	N/A	N/A

Table 2 - Average prices (REDS, 2021)

One interesting factor is that PWBCs is complaining about fluctuating prices, but so are the recyclers (Langseth, 2022). Respondent Q from Quality Plastics limited mentioned that there is an intense competition for buying plastics; *"Sellers have many options for where they can sell their plastics. If they are not happy, they can just take their plastics to a different facility"*

(Respondent Q, 07.04.2022). He further informed that the prices are never fixed, and that the price points are given by negotiations between the business (Quality Plastics limited) and the PWBCs. Respondent O from Coca Cola confirms that they suffer from fluctuating prices when they aim to sell their processed plastics. He explains this by saying that the price is decided by what the end-users are willing to pay for the end products (Respondent O, 06.04.2022). As a result, it might be challenging to create agreements with fixed prices between PWBCs and recyclers as the price fluctuations continue through the value chain.

The two main challenges among the plastic waste business collectors were high transportation costs and lack of capital. Respondent D, who transports his plastics to Mukono, rents a truck and pays around 1.000.000.000 UGX in transportation costs, which converts to approximately $268. The same respondent also struggles with lack of capital and cannot afford to buy his own truck or tools to streamline his business (Respondent D, 02.04.2022). Similar challenges were mentioned by Respondent E, who needs capital to buy motorcycles and fuel to collect more plastics (Respondent E, 02.04.2022). Respondent G does not always have sufficient capital to pay his workers, forcing him to prematurely sell his plastics to get access to capital. This leads to lower margins as he cannot fill a whole truck with plastics (Respondent G, 02.04.2022). The lack of capital results in lack of machinery to increase efficiency, and the PWBCs must resort to manual and time-consuming labor if they want to process the plastics before transportation (Langseth, 2022). These collective challenges are some of the main incentives for founding the plastic cooperative.

The current leaders of the cooperative, Respondent Group J, informed that the first idea behind the cooperative was to increase production capacity and to lower transportation costs through collaboration. Other goals behind the cooperation are to achieve a cleaner environment, especially removing bottles from drainage canals (Respondent Group J, 02.04.2022). Respondent D also informed that the municipality potentially would provide funding to the cooperative, around 30.000.000 UGX, if they can get 300-400 members to join the cooperative (Respondent D, 02.04.2022). These economic drivers have seemed to be effective as many of the PWBC were positive towards joining the cooperative.

Respondent G mentioned that one of the benefits of the cooperative is that different PWBCs can sell together, and this way save money on transportation costs (Respondent G, 02.04.2022). Respondent E informs that there have not been many advantages with the cooperative so far, but that a future benefit may be access to more capital. The respondent was also willing to process and sell plastics with a split income together with other members of the cooperative.

However, this collaboration depended on one condition; the members need to be trustworthy. The respondent further states that trust is determined by good leadership, and that the current leaders of the cooperative are trustworthy (Respondent E, 02.04.2022).

Getting enough PWBCs to join the cooperative has been a challenge, and Respondent D claims that not all are interested in collaborating (Respondent D, 02.04.2022). One of the PWBCs that is skeptical towards the cooperative is Respondent H. He does not want to collaborate with other collectors as he already has personal relationships with his buyers. The respondent claims that he does not see any benefits being a part of the cooperation, and that such a collaboration would be impossible. He is still willing to sell his plastics to members of the cooperative and wishes for better prices for the plastics sold (Respondent H, 02.04.2022).

Appendix E – Additional Information on the Territoriality in Tanzania

Current State of the Plastic Waste Problem

Dar es Salaam is the biggest city in Tanzania, found along the east coast. The EWB-project report from Tanzania revealed that the average plastic waste generation was estimated to be 0,02kg per person per day back in 2010 (Ingebo & Osborne, 2022). In 2017 the plastic waste generation in Dar es Salaam was estimated to be around 700 tons in 2017, and this is a growing trend. Dar es Salaam has a large population with around 7.000.000 inhabitants (Nyyssölä et al., n.d.). The city is experiencing rapid population growth while financial funds are scarce. This causes a decline in waste management effectiveness and over 40% of the waste in Tanzania enters the environment.

The report by Ingebo and Osborne (2022) reveals that the fraction of plastics in the municipal waste composition increased from 16% to 22% between 2012 and 2014. This increase was mainly due to an increase in PET bottles, food packaging and plastic bags. Respondent R informed that one of the biggest challenges in the project was that limited time to perform preparatory work and there was therefore a lack of specific data related to plastic waste composition and amounts. However, both Respondent S and Respondent R confirmed that PET-bottles were the biggest problem. Respondent S further informed that especially colored PET-bottles were an issue as there was already a market for transparent bottles:

> "*And specifically colored PET bottles. I knew that there was already a market for transparent bottles… We also talked to some of the pickers of plastic or the clear plastic waste. And they gave us a, the price for what they sold it for. And there was a I can't*

remember what that number is, but I could find it. I know that they sell it to Chinese recyclers." (Respondent S, 03.04.2023).

It seems like plastic bags and PET bottles are the recurring problem. This claim can be supported by cleanups organized by Nipe Fagio in Dar es Salaam in 2018. During these cleanups they collected 16 500kg of waste where 50% on average were plastics in form of plastic bags, bottles, or food packaging, which mainly are made up by PET and LDPE (Respondent S, 03.04.2023). However, it is important to note that Uganda and Tanzania are neighboring countries, which may explain the similarities in the plastic waste composition.

The government in Tanzania has taken measures to fight the rise of plastic pollution by banning plastic bags. The effectiveness of these measures can be discussed as the ban does not include other plastic packaging such as food packaging, bin bags, sanitation, and health products. There has also been calls to introduce stricter controls and legislations towards manufacturers to come up with solutions for how their products can be recycled (Ingebo & Osborne, 2022). This indicates that awareness is a principal factor to take a step in the right direction for fighting the plastic pollution problem.

Current Practices

Interviews with project participants in the Tanzanian project showed that one of the main challenges were that there was not a lot of time to perform preliminary studies about the current situation and practices, and there is therefore a lack of primary data from this project (Respondent R and S, 03.04.2023). Respondent R shared that there was a lack of infrastructure related to waste management: "*There are people that collect plastic waste, but there is very little infrastructure. There is no one that is assigned to collect it…which is why we have beach cleanings"* (Respondent R, 03.04.2023).

Drivers and Challenges

Evidence suggests that Tanzania already has a well-established market and value chain for plastic recycling. For instance, some recycling efforts are made through private investors that target HDPE, PVC, and PET plastics. Additionally, there is a market for collecting and managing clear PET bottles. Meanwhile, the increasing employment rates in Tanzania may attract more people to join the plastic waste management sector (Ingebo & Osborne, 2022). Respondent S also noticed that many people were not familiar with recycling but that they got interested when they heard that there were some business opportunities (Respondent S,

03.04.2023): This highlights the significance of economic incentives in motivating individuals and businesses to engage in plastic recycling activities.

Appendix F – Additional information on the Territoriality in Mali

Current State of the Plastic Waste Problem

The district of Bamako includes seven local authorities, six Municipalities and the District of Bamako. There is no hierarchical relationship between the local authorities. The population of Bamako was 2.094.000 in 2013, which is estimated to have grown to 2.525.931 in 2018. The city of San is located 420 km from Bamako and had a population of 69.054 In 2016, which was estimated to be 79,576 in 2018. Of the total population 67,9% are in favor of emigration, where 31,35% of this population consists of people with no level of education. The city of San is semi-rural where more than 32% of the population are devoted to agricultural practice (Zoure & Nonguierma, 2019). Mali is considered to have one of the highest tonnages of imported plastic products in the West African Economic and Monetary Union, with an annual average of 102,774 tons.

The current waste management situation causes multiple negative externalities such as accumulation of waste, which was frequently observed by Respondent T: "*You could call it acute dumpsites that suddenly spring up. People are just dropping of their waste, and they can become quite big, like mountains even"* (Respondent T, 04.04.2023). Other externalities include degrading of aesthetics and living environments due to plastic pollution, toxic emissions due to incineration, and impacts on wildlife and agriculture (Zoure & Nonguierma, 2019).

Drivers and Challenges

When it comes to assessing the drivers for plastic waste management in Bamako and San in Mali, waste pollution has a massive impact on human health and agriculture. The health situation in San is suffering of pathologies due to pollution from uncontrolled dump sites, stagnant wastewater, unmaintained gutters, and insufficient latrines. This causes infectious diseases, especially amongst children, and diarrhea accounts for 20% of deaths (Zoure & Nonguierma, 2019). From a governmental perspective a key driver could therefore be to reduce pollution levels to decrease infectious diseases and death, in addition to reduce the impact pollution has on livestock and agriculture. However, improving the current plastic waste management systems is extremely challenging due to lack of capital. In addition, Respondent U informed that there is currently a massive crisis in the country and that most of the

governmental capital is dedicated to the military and national security (Respondent U, 09.05.2023).

The municipality has undertaken some valorization actions to increase the economic value of plastic waste. Even though these measures have not been sufficient to significantly reduce the quantity of plastic waste, it is still an important driver in the informal waste sector as this provides employment and income for vulnerable groups. One of the incentives for the plastic recycling facilities in Mali is to create jobs for women and young people (Svendsen et al., 2019). This can contribute to increase economic incentives as it supports markets for plastic recycling, in addition to providing informal job opportunities. In addition, there is a current value chain for plastic recycling.

There are also multiple challenges related to plastic waste management in Mali. There is an absence of infrastructure for plastic waste management, with a lack of collection points, sorting centers, and suitable disposal sites. The collection and disposal of waste is also irregular, causing daily complaints from citizens. The feasibility study also states that the practice of burning waste has become a generalized technique, which could indicate a lack of awareness related to plastic waste management and the hazards of incineration. The informal sector also struggles with many of the similar challenges as in the other cases. There informal waste workers struggle with a lack of equipment and low margins, in addition to a lack of effective coordination between actors. (Zoure & Nonguierma, 2019).

Appendix G – Design Thinking

In the literature there are various strategies and models for these development processes, and it's normal to use different models for product development versus service development, and so on. There are however models that are suitable for multiple purposes. One of these models is "*design thinking"*, which is a model that is suitable when developing solutions for user-oriented problems. This is a method that integrates expertise from design, social sciences, engineering, and business. The idea behind the model is to produce innovative products, systems or services through blending an end-user focus with collaboration over multiple disciplines and iterative improvements (Meinel et al., 2011). There are multiple variations of the design thinking model, but Hasso Plattner has created a model consisting of five main stages: Empathize, define, ideate, prototype and testing (Hasso Plattner, n.d.).

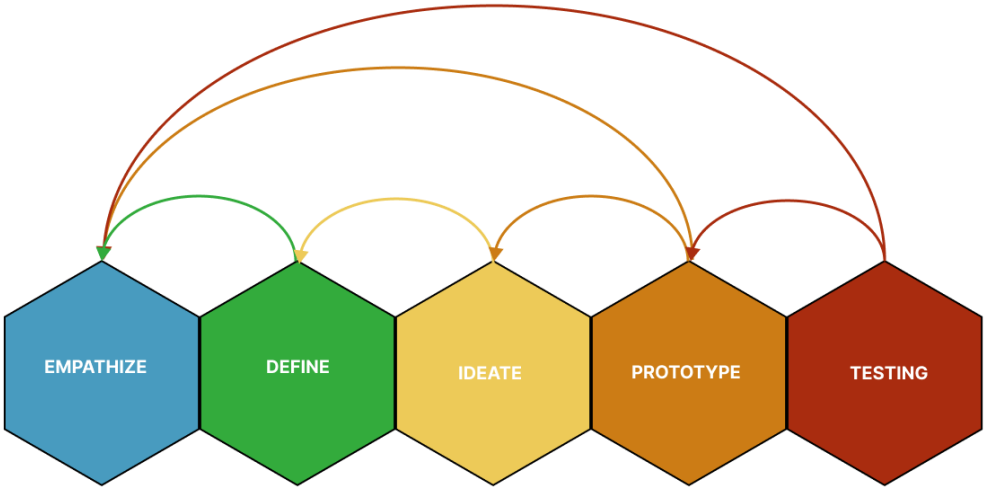


Figure 11 - The Design Thinking Process - adapted from (Hasso Plattner, n.d.)

The empathy phase involves getting to know the users to create insight and understanding of how and why they do things, their physical and emotional needs, their perspectives on the world, and what is meaningful to them. The next step is to *define* where insight from the previous step is used to create a meaningful and actionable problem statement. This is useful as the initially perceived problem might not be the true problem. The *ideate phase* involves the use of imagination, and the understanding of problem statement and users to generate a scope of solution concepts. This step is not about finding the right solution, but to generate a wide range of potential solutions. When a scope of solution concepts is defined one can move to the *prototype phase.* This phase involves generating artifacts that are used to answer questions that can move you closer to the final solution. Lastly comes the *test phase* where feedback is gathered from testing the developed prototypes. Feedback is essential to test a potential solution in a real-life context and to gain new empathy for the users. This makes it easier to find a solution that is in line with both the user's needs and wants. Insight from each individual phase has a feedback loop creates a highly iterative process that continuously builds new empathy, ideas, and knowledge, resulting in a better tailored solution to the problem statement (Hasso Plattner, n.d.). The flexibility provided through the design thinking process makes this a highly suitable model that can be adapted to both the development of new business models and technology.

Appendix H – Shredder Drawings by Human Brights

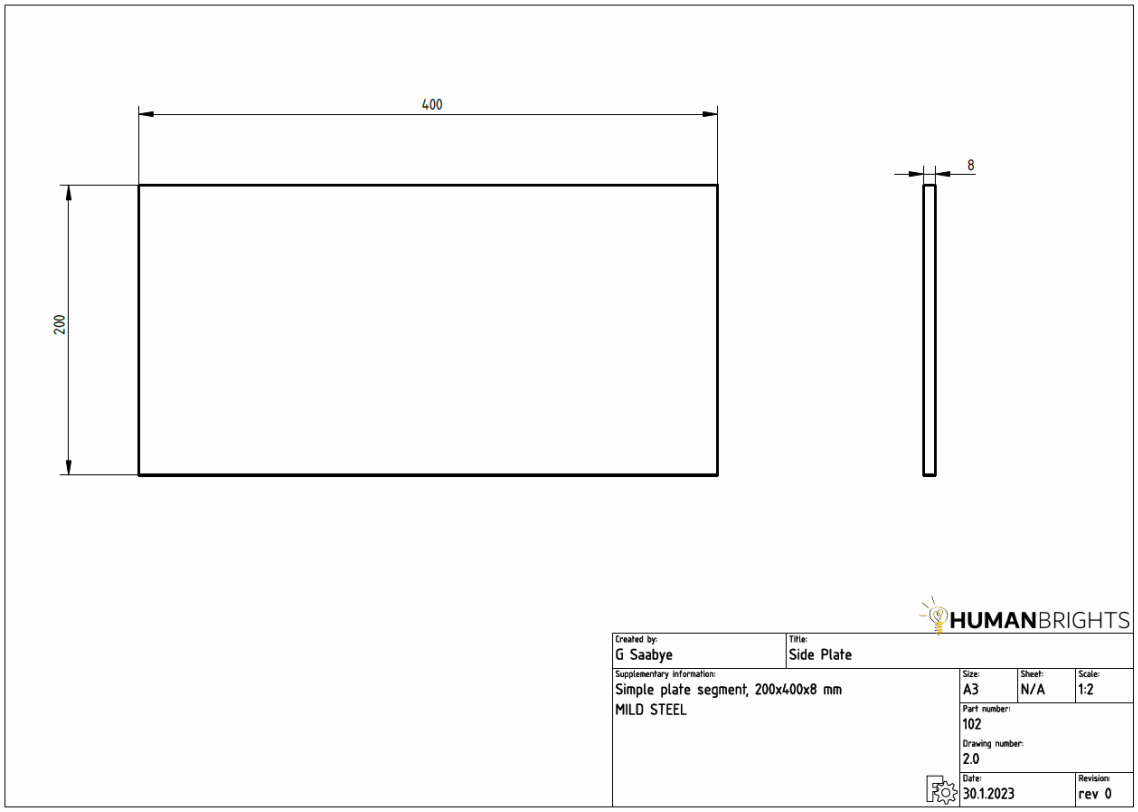


Figure 12 - Shredder side plate (Saabye, 2023b)

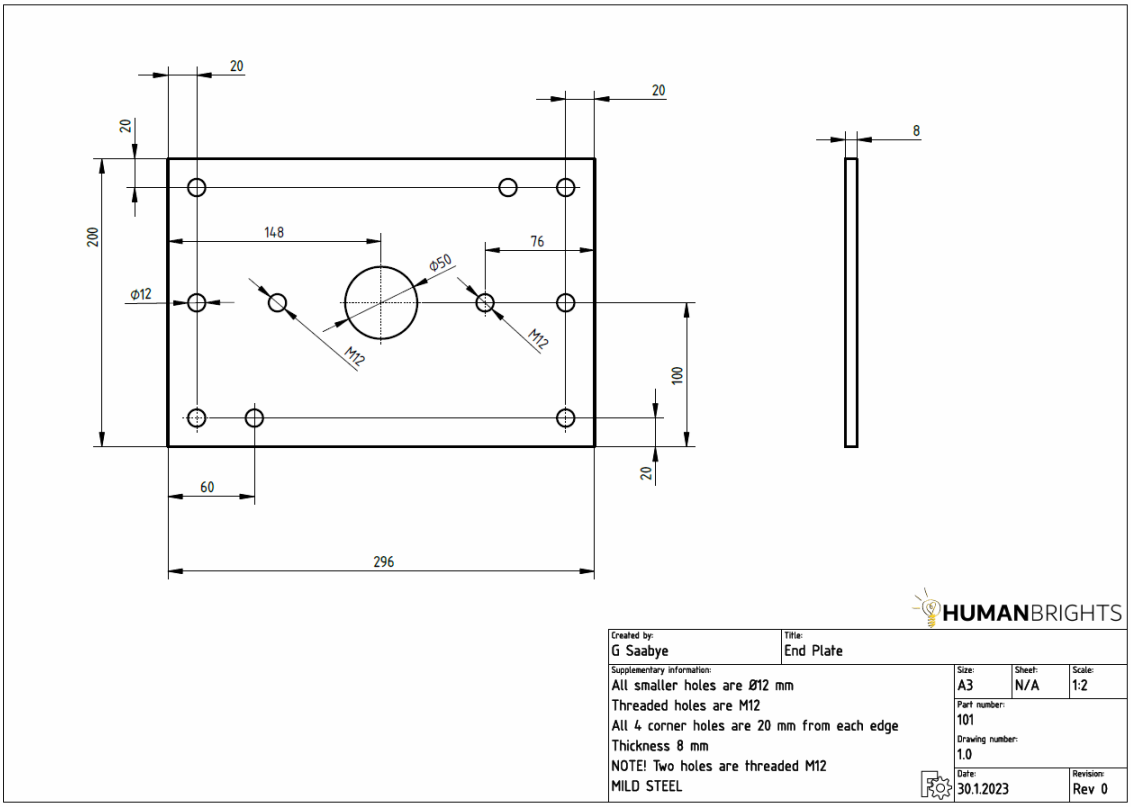


Figure 13 - Shredder End Plate (Saabye, 2023b)

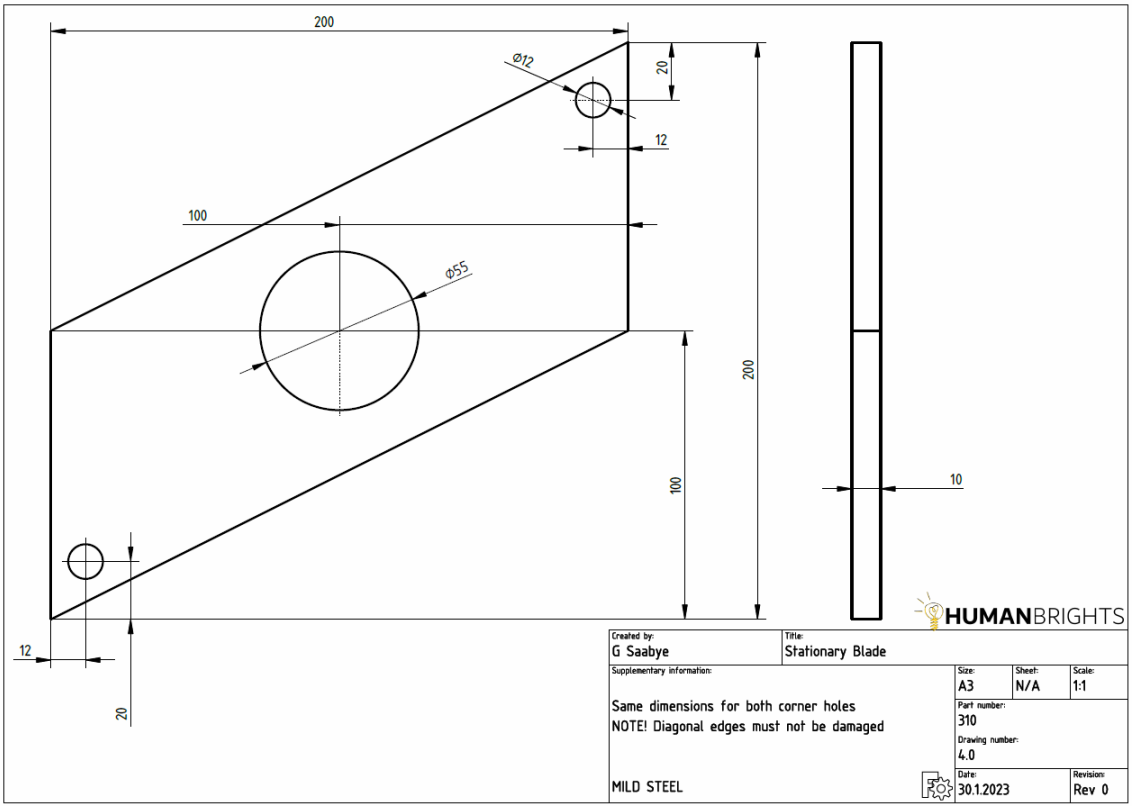


Figure 14 - Shredder Stationary Blade (Saabye, 2023b)

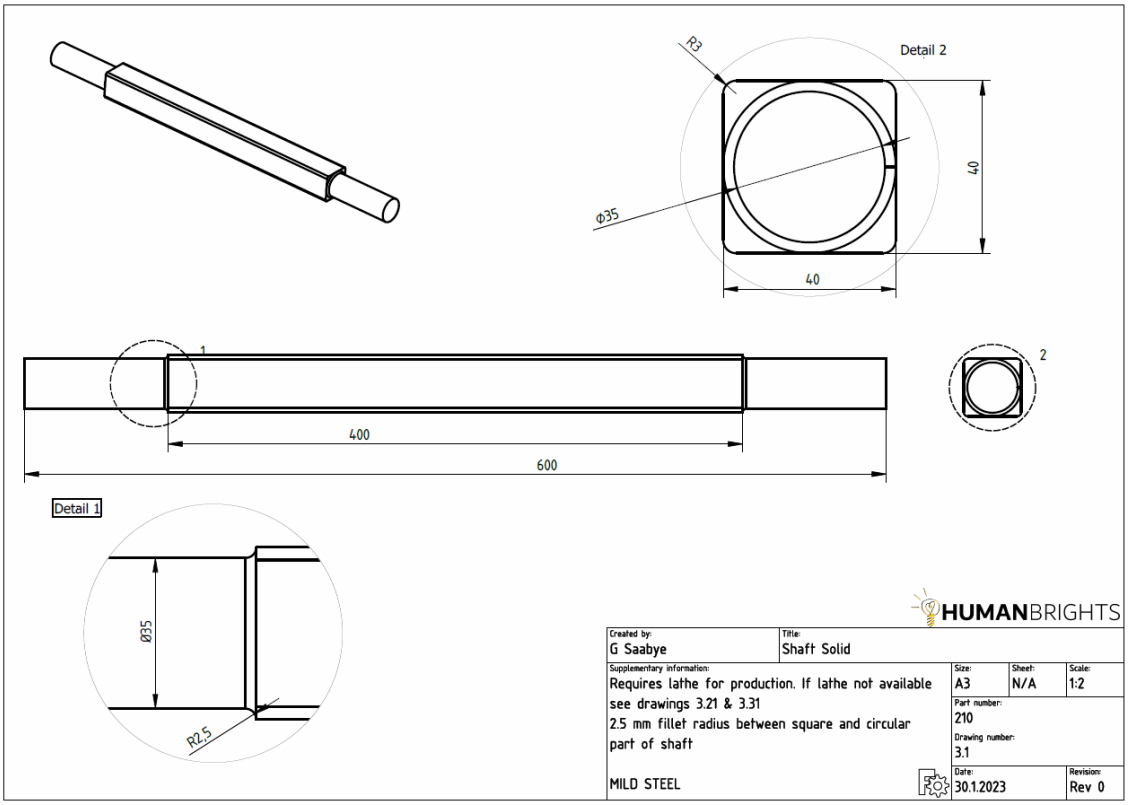


Figure 15 - Shredder Shaft Solid (Saabye, 2023b)

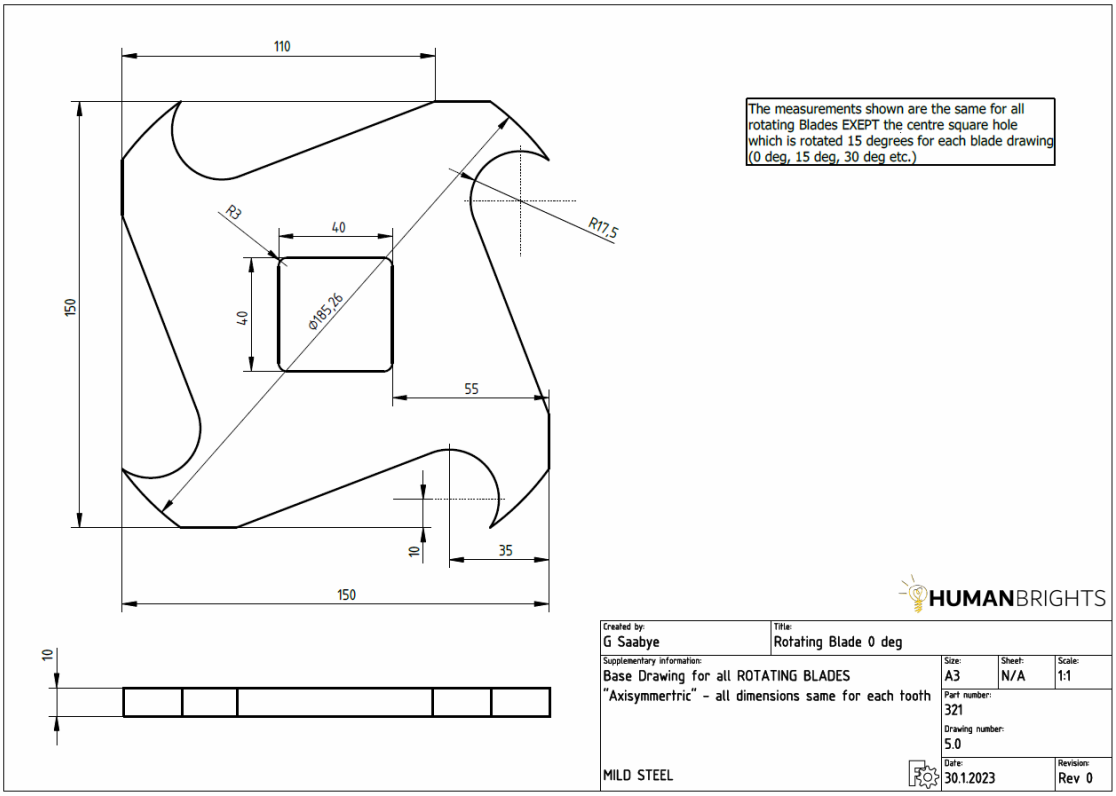


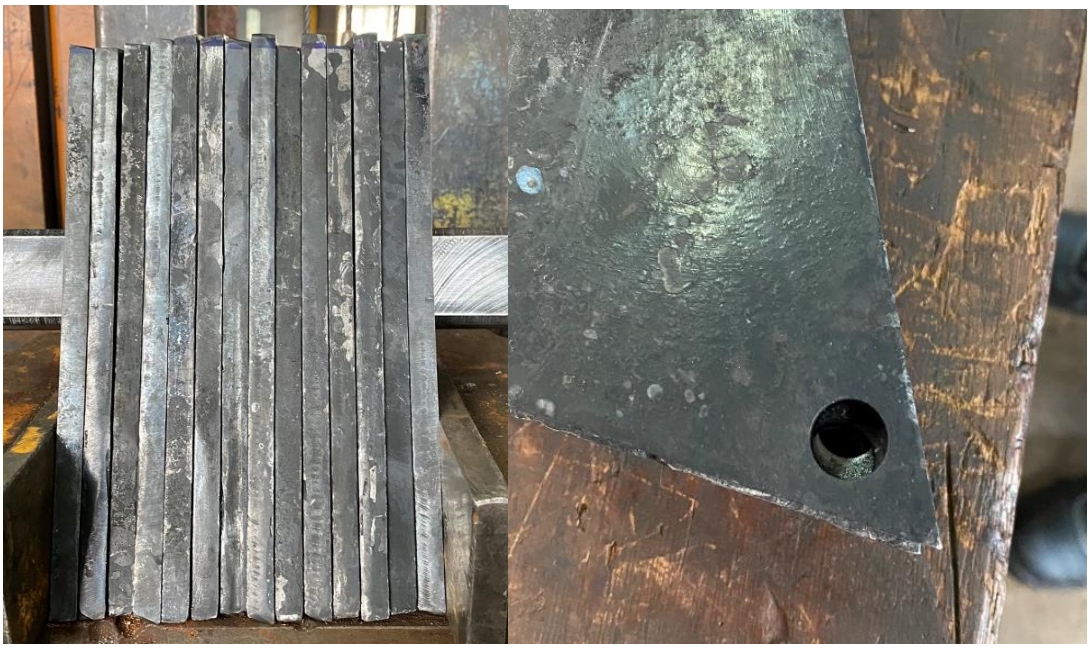
Figure 16 - Shredder Rotating Blade (Saabye, 2023b)

Appendix I – Received Shredder Parts by Nakawa Vocational Training College

All shredder parts received from Nakawa were based on the drawings from Appendix H and were fabricated in mild steel as it is hard to source hard grade steels in Uganda. The received parts had multiple deviations from the original drawings. Firstly, all parts were heat treated even though this was not specified in the drawings. This was not a critical deviation as the heat treatment is done to harden soft steel, but it also leaves a thin coating on all parts. Even though this coating is very thin, it still increases the thickness of all produced parts by 0,5-1mm, which could have an impact when assembling the machine (Langseth, 2023). An illustration of all the received parts and the coating is shown in picture 8.

Picture 8 - Illustration of coating on all shredder parts (Langseth, 2023)

Secondly, various measurements varied greatly between parts. The ends on the solid shredder shaft were not within spesificications. The diameter of the cylindrical section was specified to be 35mm, while it was measured to be 35,3mm. The biggest issue was the stationary blades were the measurements were different for each part. As illustrated in picture 9, the total size varied between each blade and they were not flush with eachother. The maximum deviation measured was 6mm. Additionally, and most crucially, the corner holes on each blade were at largely variated distances from the edges and did hence not align with eachother. These deviations were up to 10mm from the drawing (Langseth, 2023). This is illustrated in picture 10.



Picture 9 and 10 – Size Variations and Unalignment in Stationary Blades (Langseth, 2023)

There were also some variations in size on the shredder teeth. Some of the center holes were not cut straight, resulting in some of the teeth not fitting the shredder axle. As shown in picture 11 the total size of each rotating blade (teeth) varied, which could result in the blade coming in unwanted contact with the shredder box during operation. Thirdly, there were some minor deviations where some of the plates for the shredder box were bent and needed to be straightened. One of the stationary blades were also bent, but this was not critical as the order from Nakawa included spare parts (Langseth, 2023)

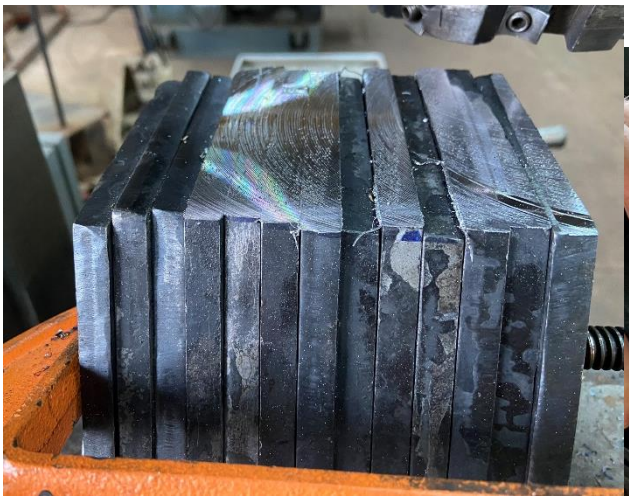
Picture 11 – Illustration of Rotating Blades (Teeth) (Langseth, 2023)

Appendix J – Modified Shredder Parts, Uganda

The first that was taken to rectify the received shredder parts was to try to remove most of the coating from the heat treatment. This was done by soaking the parts in kerosene and wiping off the excess with cloth. This removed some of the coating but was not effective to remove all of it. At this stage we did not take further measures to clean the parts. The cleaning processes are illustrated in picture 12. The next step was to manually file all the center holes on the rotating blades (teeth) so that they would fit the shredder axle. The end plates were bent and was straightened using a hydraulic press (Langseth, 2023).

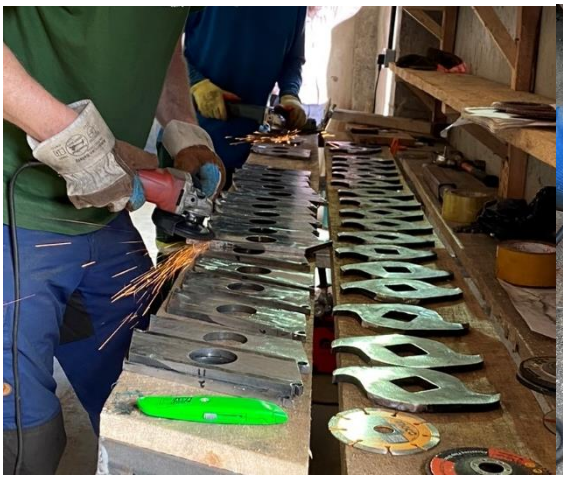
Picture 12 - Cleaning parts (Langseth, 2023)

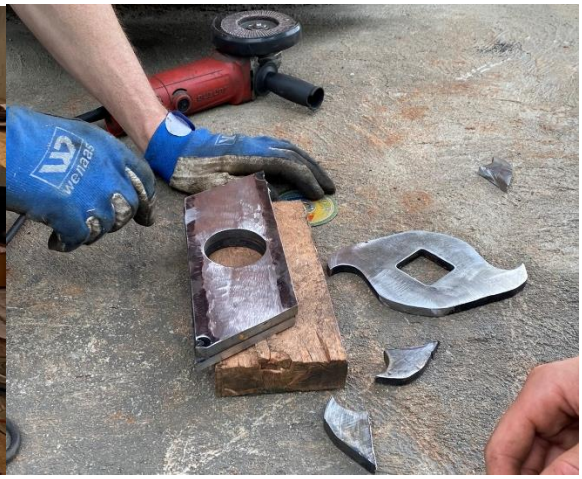
The next step was to rectify and modify the stationary blades. All the stationary blades were first mounted on the shredder axle to ensure that the center holes were aligned. They were then clamped together, before milling off 10mm in total. This is illustrated in picture 13. The cornered holes could not be rectified which meant that we could not secure the stationary blades with two rods as intended in the shredder design. As a result, only the shredder box and the shredder axle would hold the stationary blades in place, risking slight horizontal movement between the blades. After further testing we found that some of the rotating blades (teeth) were too big and hit the shredder box during operation, causing unwanted friction. All teeth were therefore measured and filed to be within specifications using a stationary grinder. This is illustrated in picture 14. The stationary axle was rectified to be within specifications using a lathe (Langseth, 2023).



Picture 13 - Milling the stationary blades (Langseth, 2023) *Picture 14 – Grinding rotating blades (Langseth, 2023)*

After assembling the shredder there was a lot of friction in the shredder box. To reduce friction, we attempted to pour sand in the shredder during operation to sand off more of the coating on the parts. After additional testing in Mityana we discovered that there still was too much friction between the stationary and rotating blades when mounted in the shredder box, causing the motor to struggle. To reduce friction, we decided to reduce thickness on the main contact surface on both the stationary and rotating blades using an angle grinder. In addition, two teeth from each rotating blade were cut off to reduce the power needed from the motor to run the shredder. These modifications are illustrated in picture 15 and 16 (Langseth, 2023).





Picture 15 – Grinding Stationary Blades (Langseth, 2023) *Picture 16 – Modifying Rotating Blades (Langseth, 2023)*

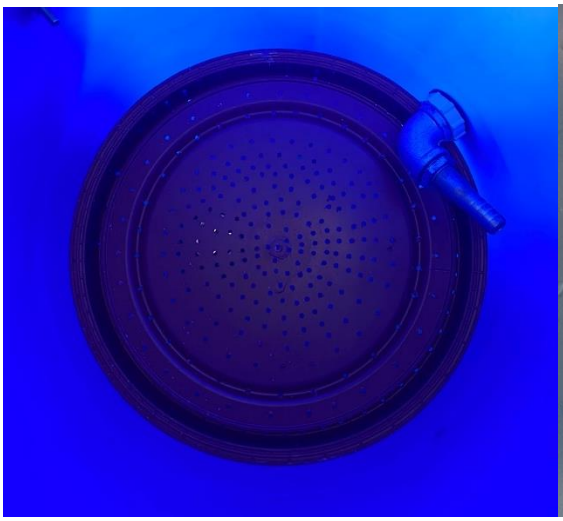
Appendix K – Washing and Water Cleaning System and Drying System, Uganda

The washing system was built mainly using 4 plastic tanks, a water pump, some basic plumbing parts, a hose, and some cloth as a filter. The dirty and shredded plastics enter from the top and goes into tank 1 (T1). Picture 17 illustrates the flow inside the washing and water cleaning system. The red arrow shows the plastic intake, while the orange, yellow and green arrow shows the water flow where the water gradually gets cleaner. The black arrows symbolize the sediments that sink to the bottom of each tank.

Picture 17 - Washing System Flow Chart (Langseth, 2023)

Inside tank 1 there is a sieve that keeps the plastics inside T1 (picture 18), while the dirty water flows down to T2. Dirt and particles from the dirty water will sink to the bottom of the tank, while the remaining water flows through a cloth filter and into T3 (picture 19). The same process happens in T3, making the water cleaner for each step. The water then flows through a new filter and into T4. In T4 there is a water pump that pumps the clean water back to T1, creating movement that cleans the plastic in the first tank (picture 20). The water pressure created from the pump creates an even flow of water through the washing system. When the

plastic is clean it needs to be manually removed from T1. The sediments from the dirty water in T2-4 also needs to be removed manually. This system allows water to be reused multiple times, minimizing water usage. The system could further be improved by installing valves on the bottom of T2-4, which connects to a drainage pipe that drains the sediments to a spill tank (Langseth, 2023).



Picture 18 - Plastic Sieve in T1 (Langseth, 2023)

Picture 19 – Cloth Filter T2-4 (Langseth, 2023)

Picture 20 - Water Pump in T4 Plastic Sieve in T1 (Langseth, 2023)

The drying system was put together using a mesh-fabric and some plastic string that was found at the facility in Mityana. The mesh was cut out in a box shape and was tied together using plastic string. The mesh-basket was then hung from a shelf inside the facility, and fans will be placed in front of it to provide airflow. It is important to note that the drying system only was meant to be a simple demonstration of how it can be made and is not necessarily the final solution. The drying system is illustrated in picture 21 and 22.

Picture 21 – Mesh Fabric (Langseth, 2023)

Picture 22 – Illustration of Drying System (Langseth, 2023)

Appendix L – Precious Plastic

Precious Plastic is a project that aims to reduce plastic waste by providing people with the tools, platforms and knowledge needed to recycle plastic locally. The project was started by Dave Hakkens in 2012, who developed a range of machines for plastic waste recycling. These have an open-source design and are shared online for free so that anyone can replicate them. Their goal is to combine people, machines, platforms, and knowledge to create an alternative and global system for plastic recycling. Anyone can join the Precious Plastic Community and start a collection point, community point, machine shop, or other plastic recycling workspaces (One Army, n.d.; Precious Plastic, n.d.-c).

Today Precious Plastic currently has seven machines in their portfolio for various needs and outputs. The machines are divided into three categories, basic, pro, and community. The basic machines are designed to be easy to build and replicate and consist of a shredder, extrusion, and injection machine. The pro series are bigger machines that can process and recycle bigger volumes of plastics. This series consists of a shredder pro, extrusion pro, and a sheet press. The community series includes tools and machines developed by the Precious Plastic community. This series consist of a bicycle shredder, all in one machine, extrusion on wheels, recycling in a box that consists of a shredder and injection machine, and a 3D printing add on (Precious Plastic, n.d.-d).

Appendix M – Lean 5S Principles

The lean 5S principles is a method to organize and maintain a workplace to improve productivity, efficiency, and safety, where each S stands for its own principle. The first S is to *sort* unnecessary items from necessary items. The second S is to *set* a designated place for all necessary items in a logical and accessible manner. The third S is shine which involves keeping the workplace clean and tidy to ensure a safe and efficient workplace. The fourth S is to *standardize* by managing and maintaining performance, for example through clear guidelines and procedures. The fifth S is to *sustain* by implementing standards for optimal conditions, where the goal is to maintain the improvements achieved. Some companies also include *safety* as a sixth S. By implementing these principles one can achieve a more streamlined and productive workspace (Pannell, 2020).

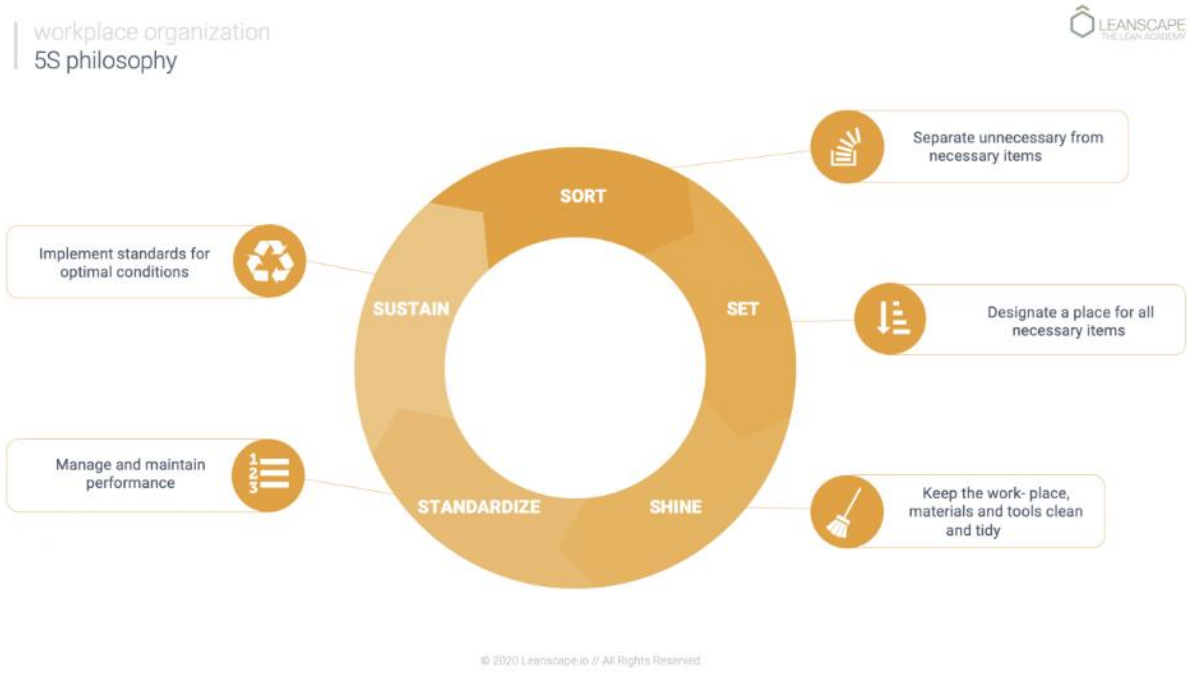


Figure 17 - The 5S Philosophy (Pannell, 2020)

Appendix N – Business Calculations, Uganda

To assess the profitability of the plastic recycling facility in Mityana some financial calculations were performed based on information the baseline study, PWBCs, and recyclers (Langseth, 2022; REDS, 2021).

Transportation costs

The facility does not currently have sufficient capital to buy a truck for transportation, resulting in two transportation options. The first option is to sell plastics to Coca Cola, who informed that they charge a transportation cost of 50-100 UGX/kg, based on transportation distance (Respondent O, 06.04.2022). The second option is to rent a truck at a cost of 1.000.000 UGX, including fuel (Langseth, 2022). The table below shows calculations per kg, depending on the truck load and plastic type.

Truck-load size (tons)	Transportation Costs (UGX/kg)	Comment
0,5	2 000	*Likely applicable for unshredded PET*
1	1 000	
2	500	
4	250	*Likely applicable for unshredded HDPE*
6	166	
8	125	
10	100	*Likely applicable for shredded plastic*

Table 3 - Transportation costs per kg plastics to Kampala with a rented truck (Schippert, 2023)

Potential buying price from PWBCs

Firstly, The SUWASO project does not want to be a competitor to the PWBCs, but rather encourage them to work and collect more plastics. The goal is to offer a higher payment for the collected plastics than they are currently getting. Based on the information given by the PWBCs, collecting PET bottles is currently not profitable as the transportation costs are higher than the selling price. The facility seeks to pay the PWBCs higher prices to increase the margins on collecting PET bottles and HDPE. A calculation of what the facility can offer the PWBCs are shown in table 4 below. An assumption is that the PWBCs are willing to sell their plastics to the facility for this price. The price offered is lower than they would get in Kampala, but as they no longer have any transportation costs the margins are better than their current prices (Schippert, 2023).

Assumed collection price from PWBCs				
	Value if selling in Kampala (UGX/kg)	Transportation costs (UGX/kg)	Revenue minus transportation costs (UGX/kg)	Potential buying price (UGX/kg)
PET	550,0	2 000,0	-1 450,0	150,0
HDPE (Basins and buckets)	813,0	250,0	563,0	600,0
HDPE (Jerrycans)	1 700,0	250,0	1 450,0	1 500,0

Table 4 - PWBCs income based on information collected through interviews, from sales in Kampala, transportation costs, and potential buying price directly from PWBCs in Mityana (Schippert, 2023)

Machine specifications and production costs

As the machines currently have not been tested, the production volume is unknown. Calculations are therefore made for different production rates, ranging from 20kg/h to 35kg/h. The operational hours for the facility have not been decided, and further calculations are based on two different scenarios. The first scenario assumes production of 6 hours daily, 6 days a week, and 4 weeks per month. The second scenario assumes production of 8 hours daily, 5 days a week, 4 weeks per month (Langseth, 2023). The production costs based on energy consumption and energy prices are shown in table 5 and 6 below. Additionally, it is suggested to put away a fixed sum of 400.000 UGX/month for future maintenance, and other fixed production costs are estimated to be 1.850.000 UGX/month in the first year, and 2.450.000 UGX/month from the second year.

Production Costs							
	kW	Hours/month	Electricity costs (UGX)		VAT (20%)	Total costs (UGX)	
Shredder	2,0	144	UGX	747,5	20 %	UGX	129 168,0
Washer	0,5	144	UGX	747,5	20 %	UGX	129 168,0
Dryer	0,5	144	UGX	747,5	20 %	UGX	129 168,0
Total						**UGX**	**387 504,0**

Table 5 - Production costs, scenario 1 (Langseth, 2023)

Production Costs							
	kW	Hours/month	Electricity costs (UGX)		VAT (20%)	Total costs (UGX)	
Shredder	2,0	160	UGX	747,5	20 %	UGX	143 520,0
Washer	0,5	160	UGX	747,5	20 %	UGX	143 520,0
Dryer	0,5	160	UGX	747,5	20 %	UGX	143 520,0
Total						**UGX**	**430 560,0**

Table 6 - Production costs, scenario 2 (Langseth, 2023)

Selling price for shredded plastics

A potential sales price for the shredded plastics are based on potential prices given by Respondent O (Langseth, 2022)

Sales income	
	UGX/kg
PET	900
HDPE (basins and buckets)	1350

Table 7 - Potential selling price, shredded plastics(Langseth, 2022)

Contribution margins

Based on the costs and prices provided several contribution margins were calculated based on different production rates, transportation costs, and operating hours. The calculations shown are based on the fixed production costs for the first year of production. For scenario 1, with 144 operational hours per month, the minimum production rate must be a minimum of 29kg/h for the business case to be profitable. This assumes a transportation cost of 100 UGX/kg, which gives a low positive result. If the facility can sell plastics to Coca Cola with a transportation cost of 50 UGX/kg, the result increases to 285.696 UGX/month. Table 8 and 9 show potential profits for PET and HDPE, assuming 144h/month, production of 29 kg/h, with a transportation cost of 100 UGX/h.

	Amount per month (kg)	Price (UGX/kg)	Turnover	
Shredded (PET)	4 176,0	900	UGX	3 758 400,0
Sum revenue			**UGX**	**3 758 400,0**
Material costs	4 176,0	150,0	UGX	626 400,0
Production costs	4 176,0	92,8	UGX	387 504,0
Transportation costs	4 176,0	100	UGX	417 600,0
Contribution margin			**UGX**	**2 326 896,0**
Fixed costs			UGX	2 250 000,0
Result			**UGX**	**76 896,0**

Table 8 – Shredded PET, Scenario 1 (Langseth, 2023)

	Amount per month (kg)	Price (UGX/kg)	Turnover
Shredded (HDPE)	4 176,0	1 350,000	5 637 600,0
Sum revenue			**5 637 600,0**
Material costs	4 176,0	600,000	2 505 600,0
Production costs	4 176,0	92,793	387 504,0
Transportation costs	4 176,0	100,000	417 600,0
Contribution margin			**2 326 896,0**
Salary			1 850 000,0
Maintenance			400 000,0
Result			**76 896,0**

Table 9 – Shredded HDPE, scenario 1 (Langseth, 2023)

If keeping the same assumptions but changing operational hours to scenario 2 with 160h/month and a production rate of 26kg/h, the profits are significantly higher, see table 10 and 11. With increased operational hours the production rate needs to be a minimum of 26kg/h to be profitable.

	Amount per month (kg)	Price (UGX/kg)	Turnover	
Shredded (PET)	4 640,0	900	UGX	4 176 000,0
Sum revenue			**UGX**	**4 176 000,0**
Material costs	4 640,0	150,0	UGX	696 000,0
Production costs	4 640,0	92,8	UGX	430 560,0
Transportation costs	4 640,0	100	UGX	464 000,0
Contribution margin			**UGX**	**2 585 440,0**
Fixed costs			UGX	2 250 000,0
Result			**UGX**	**335 440,0**

Table 10 - Shredded PET, Scenario 2 (Langseth, 2023)

	Amount per month (kg)	Price (UGX/kg)	Turnover
Shredded (HDPE)	4 640,0	1 350,000	6 264 000,0
Sum revenue			**6 264 000,0**
Material costs	4 640,0	600,000	2 784 000,0
Production costs	4 640,0	92,793	430 560,0
Transportation costs	4 640,0	100,000	464 000,0
Contribution margin			**2 585 440,0**
Salary			1 850 000,0
Maintenance			400 000,0
Result			**335 440,0**

Table 11 - Shredded HDPE, Scenario 2 (Langseth, 2023)

During the first start-up months of production the maintenance costs can be reduced to ensure that the facility is earning profits. However, these costs should not be neglected as maintenance is essential to ensure long-term operation.

Appendix O – Triple Layer Business Model Canvas, Uganda

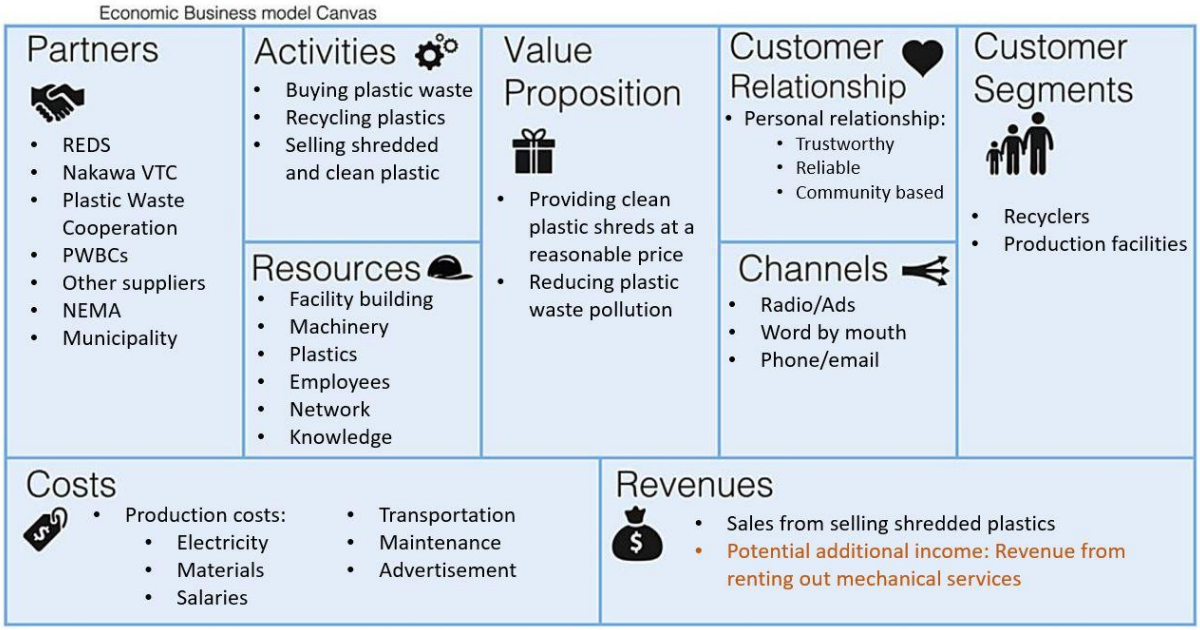


Figure 18 - Economic Layer, TLBMC, Uganda (Langseth, 2023)

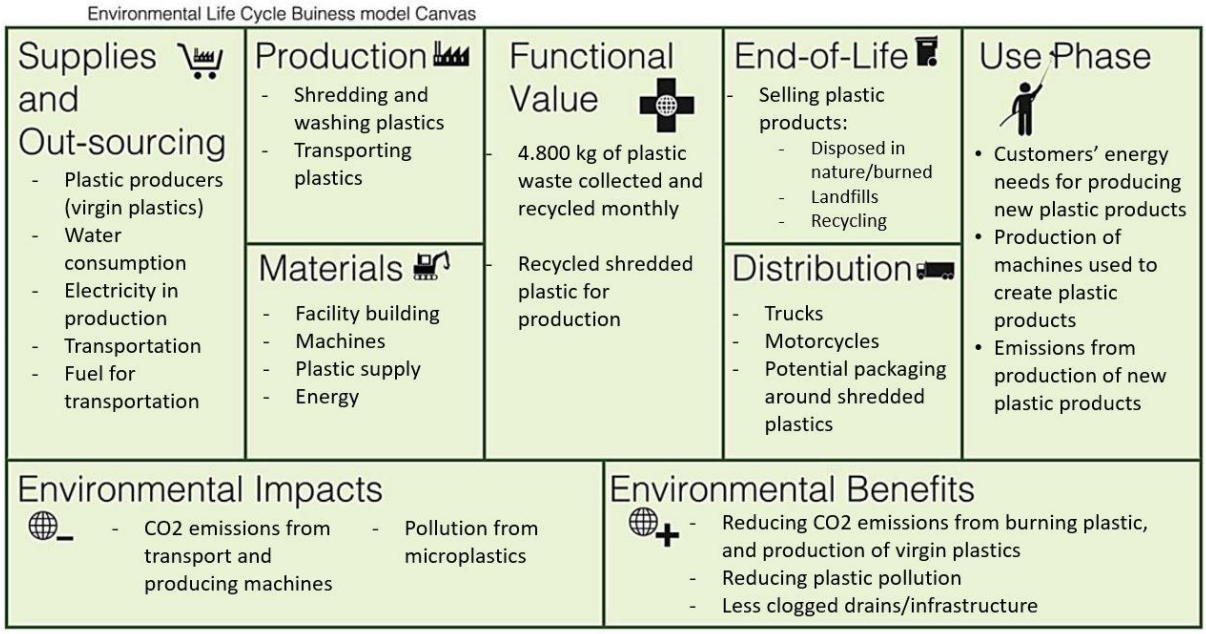


Figure 19 - Environmental Layer, TLBMC, Uganda (Langseth, 2023)

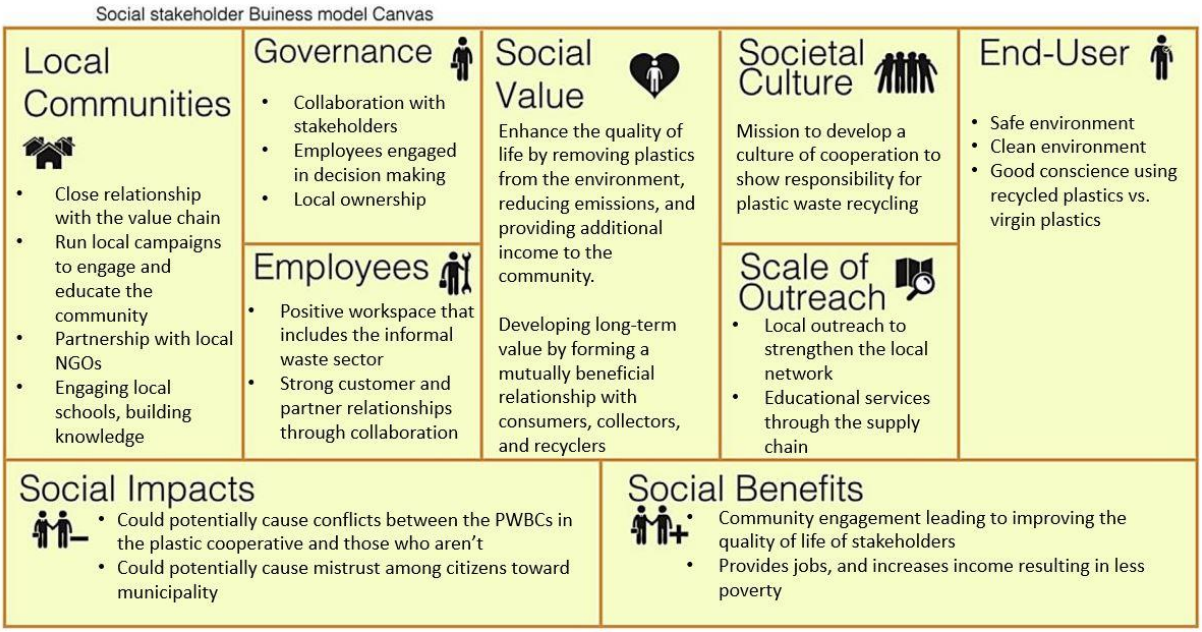


Figure 20 - Social Layer, TLBMC, Uganda (Langseth, 2023)

Appendix P – Triple Layer Business Model Canvas, Tanzania

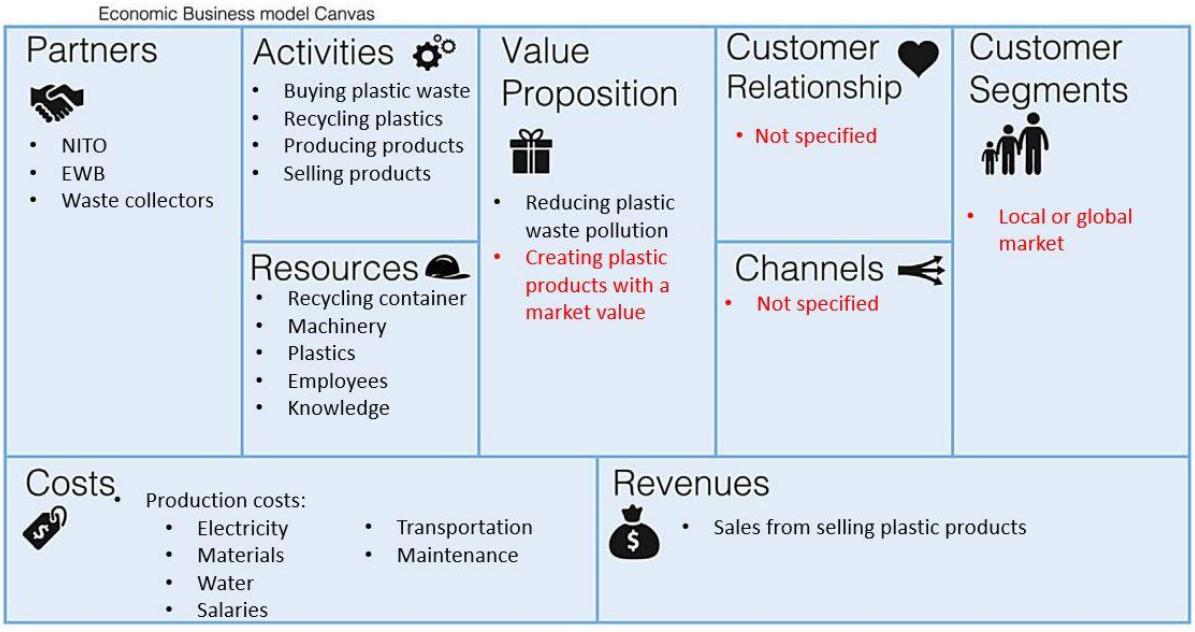


Figure 21 - Economic Layer, TLBMC, Tanzania

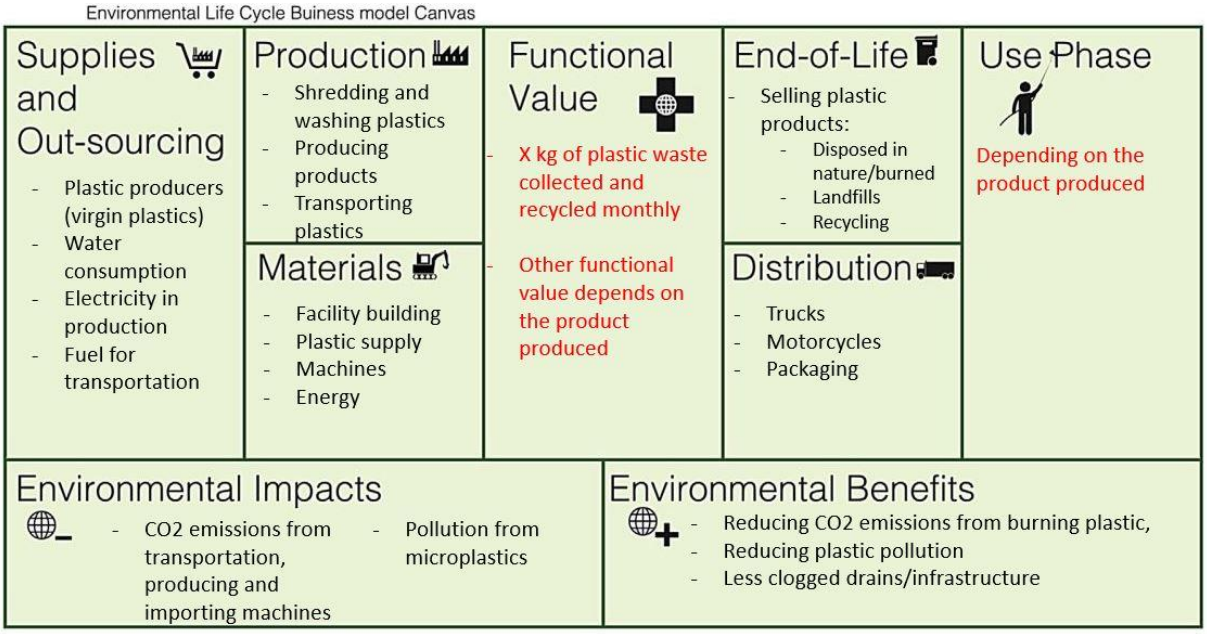


Figure 22 - Environmental Layer, TLBMC, Tanzania

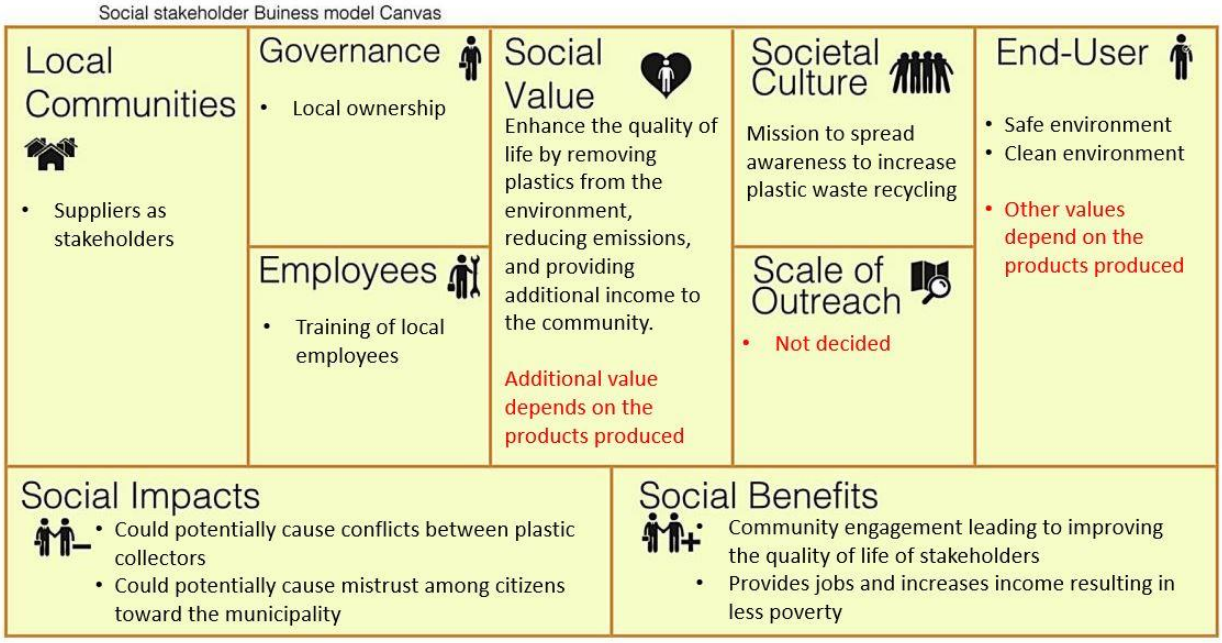


Figure 23 - Social Layer, TLBMC, Tanzania

Appendix Q – Triple Layer Business Model Canvas, Mali

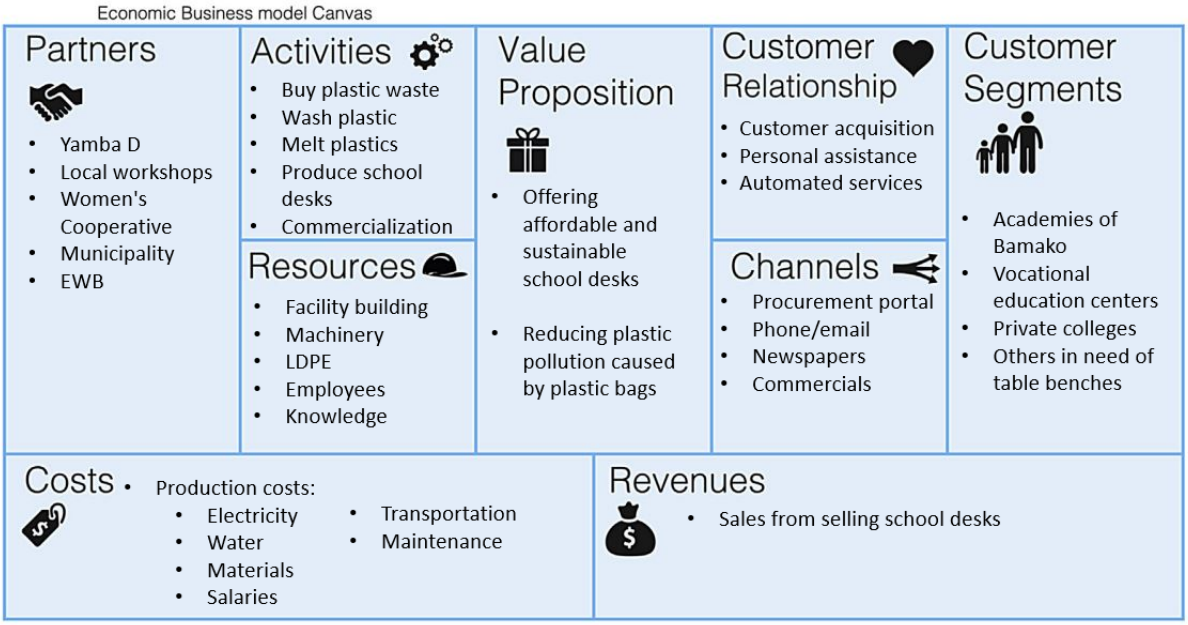


Figure 24 - Economic Layer, TLBMC, Mali

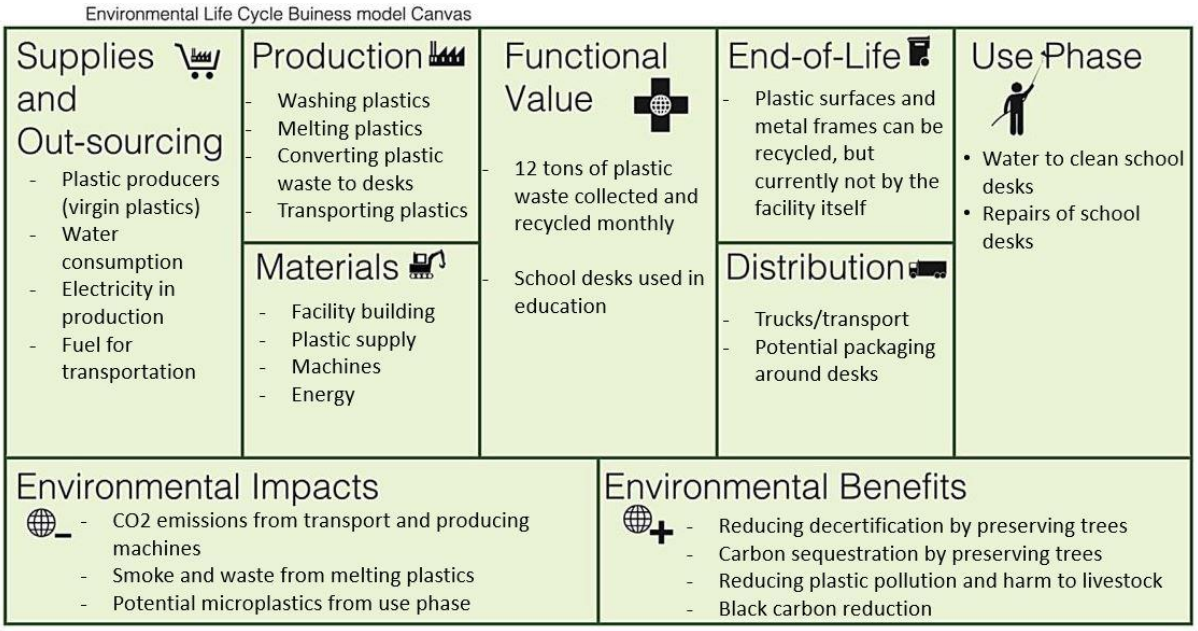


Figure 25 - Environmental Layer, TLBMC, Mali

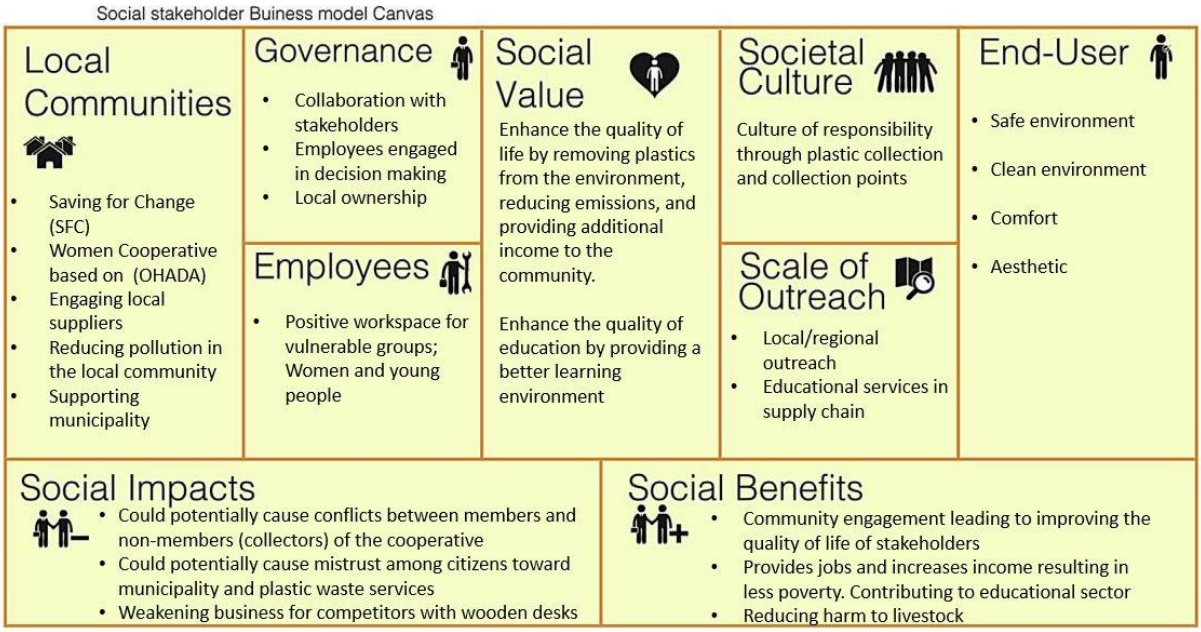


Figure 26 – Social Layer, TLBMC, Mali