A Recommended Recycling Processing System for the Informal Waste Collectors of Oshakati, Namibia

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An Interactive Qualifying Project submitted to the Faculty of Worcester Polytechnic Institute in partial fulfilment of the requirements for the degree of Bachelor of Science.

1 May 2017

Report Submitted to:

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ABSTRACT

The goal of this project was to increase the earnings of informal waste collectors (IWCs) in Oshakati, Namibia by recommending a recycling processing system to add value to their collected materials. Through research, interviews, and cost-benefit analyses the project team discovered that a small-scale, solar-powered plastics and aluminum shredding machine funded by the Oshakati Town Council has the potential to more than quadruple IWC monthly earnings from their current state.

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EXECUTIVE SUMMARY

Two major challenges facing the country of Namibia are high unemployment and an undeveloped waste management system. These challenges create an informal recycling industry where unemployed Informal Waste Collectors (IWCs) collect and sort recyclable materials in their town dumpsites and sell them to private recycling packaging companies. These IWCs work long hours in hazardous conditions and receive very low payments for their efforts. In the town of Oshakati, the fifth-largest urban settlement in Namibia, 30 IWCs work in the local dumpsite and earn a monthly income of just N$190 (Haukena, 2017). This income is 31.5% below the Namibia poverty line classifying Oshakati IWCs as "severely poor" (Namibia Statistics Agency, 2012a).

Oshakati IWCs' earnings are low primarily because of the low purchase prices for recyclable materials set by the private recycling packaging companies in the region. These companies purchase recyclables from IWCs, bale them, and sell them at a higher price to further processing companies in South Africa, as there are currently no large-scale recycling processors operating in Namibia. Due to the inefficiencies in this system, the recycling packaging companies offer extremely low prices for the raw, unprocessed recyclables IWCs collect and sort at the dumpsites. By adding value to the recyclables they collect, IWCs could appeal to new markets and potentially increase their selling prices. Processing performed locally by Oshakati IWCs could add value to the recyclables and result in increased earnings for IWCs.

The goal of this project was to increase the earnings of IWCs in Oshakati, Namibia by recommending a recycling processing system to add value to their collected materials. This project limited the scope of a "recycling processing system" to include two elements: recycling processes and operational strategies. The recommended processes include the technique for preparing a particular recyclable material for industry and the associated resources and equipment needed. The operational strategies detail the type of organization that owns and operates the processing equipment and the method that the organization employs to integrate the IWCs into this system. To achieve the project goal, the team established a set of three objectives. The study began by observing existing recycling systems and interviewing key stakeholders. From the observations and interviews, the investigation evaluated potential strategies for adding value to recyclable materials. Finally, the team used these process evaluations to recommend a recycling processing system for IWCs in Oshakati.

The project accomplished these objectives through a variety of methods including interviews, focus groups, open discussion forums, interview coding, and cost-benefit analyses. Initially, the team interviewed stakeholder groups: IWCs in Ongwediva, Ondangwa, and Oshakati; the two recycling packaging companies in the area, Rent-A-Drum (RAD) and Wilco Recycling Company; and the Oshakati Town Council (OTC). The information obtained from these stakeholder groups helped determine the most profitable materials to process in the Oshakati dumpsite. Through case study reviews, background research, and the considerations of the stakeholders, the team identified potential processes for the selected materials, and a cost-

benefit analysis evaluated the economic potential of these processes. The project's final recommendations to the town of Oshakati included the top-performing processes as well as operational strategies for integrating the processing system into the Oshakati dumpsite.

At the interviews and discussion forums, the IWCs at all three locations revealed that their primary concerns regarding their work in the dumpsite are unfair payment, low earnings, and unsafe working conditions. The IWCs reported that RAD and Wilco offer the IWCs low prices for their recyclables, and frequently underpay. The IWCs emphasized that they are interested in any initiative that will ensure they are paid fairly and increase the prices at which they are able to sell their materials. When introduced to the team's project, all stakeholder groups responded positively, expressing that recyclable processing by IWCs in the dumpsite would positively impact the Oshakati recycling system. The stakeholders expressed that the principle role of a dumpsite processing system would be to increase the value of recyclables so that IWCs could sell the processed materials at higher prices. The stakeholders also stated that the processing system would need to have a suitable local market to sell to and would need to be safe to operate.

The stakeholder responses determined that a small-scale processing machine would be appropriate for the Oshakati dumpsite. A 2013 study on waste quantities in Northern Namibia by Alsins et al. determined the most abundant materials in the Oshakati dumpsite and the volume of materials deposited at the dumpsite per day by all possible means. The combination of this data with the current unbaled and baled sale prices provided by Wilco estimated a lower bound revenue for each material that would result from processing and selling the maximum available quantities of various recyclables in the dumpsite each week, depicted in Figure 1. The purple bars represent the potential revenue from selling unbaled and unprocessed materials, as the Oshakati IWCs currently sell to Wilco, and the blue bars represent the potential revenue from selling baled materials, as Wilco currently sells to further processing and manufacturing companies. Using this information, this project concluded that Low-Density Polyethelene (LDPE) plastic bags, Aluminum cans, High-Density Polyethelene (HDPE) plastics, and Polyethylene Terephthalate (PET) plastic bottles have the greatest potential to undergo an increase in selling value as a result of baling or other processing of these recyclables.

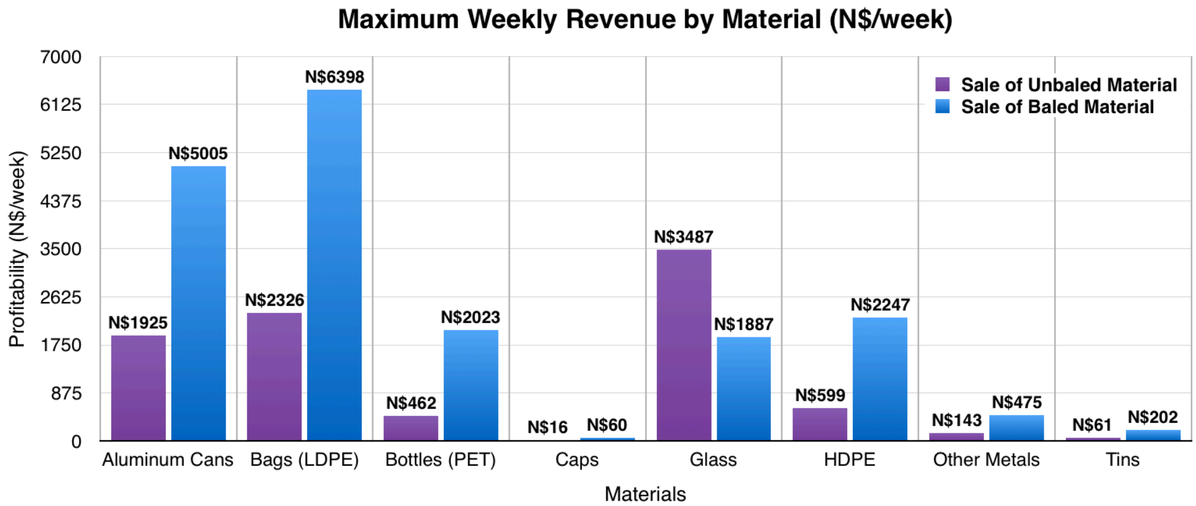

Figure 1: Maximum weekly revenue from unbaled and baled recyclables in the Oshakati dumpsite in 2013 (modified from Alsins et al., 2013)

The first stage in the recycling process for all three types of plastics as well as aluminum is to shred the materials. A small-scale machine can perform the shredding process, making it a viable candidate for a recycling operation in the Oshakati dumpsite. The study investigated different types of shredding machines, as well as external power sources for industrial machines, since the Oshakati dumpsite does not currently have access to an electrical supply. The study further investigated three equipment options, which Table 1 summarizes.

Table 1: Shredding equipment options to investigate for the Oshakati dumpsite

Machine Type	Machine Name	Power Source Type	Power Source Name	Materials Processed
Industrial Shredding Machine	German MOCO Shredding Machine AZ 09F	Solar	Solar Age Namibia SHS4 Solar Panel	Plastics and Aluminum
Industrial Shredding Machine	German MOCO Shredding Machine AZ 09F	Diesel Generator	Namibian 13 kVA Standby FAW Generator	Plastics and Aluminum
Bicycle Shredder		Manual		Plastics

The next step in this study was to compare these three processing equipment options through a cost-benefit analysis. The cost-benefit analysis included the initial equipment cost, annual maintenance, fuel costs, and annual profit from selling the shredded materials. This analysis calculated the total cost-benefit ratio as well as the monthly income per IWC as a result of the shredding process, assuming that the 30 IWCs operating in the Oshakati dumpsite will remain there throughout the 11-year analysis period. For each of the three equipment options, the team separately analyzed the effects of processing all available plastics, aluminum cans, and a combination of plastics and aluminum. Note that this investigation only analyzed the bicycle shredder for processing plastics, as this machine is not capable of shredding aluminum. Table 2 summarizes the results of the cost-benefit analysis for the seven potential processing systems, highlighting the top three performers.

Table 2: Cost-benefit analysis results for potential processing systems

Machine Type	Power Source	Material Processed	11 Year Cost-Benefit Ratio	Average Monthly Profit Per IWC in First 11 Years
Industrial Shredder	**Solar**	**Plastic & Aluminum**	**10.92**	**N$2,056.49**
Industrial Shredder	**Generator**	**Plastic & Aluminum**	**4.59**	**N$1,770.64**
Industrial Shredder	**Solar**	**Plastic**	**7.43**	**N$1,333.55**
Industrial Shredder	Generator	Plastic	3.23	N$1,064.25
Industrial Shredder	Solar	Aluminum	3.49	N$515.61
Industrial Shredder	Generator	Aluminum	1.52	N$246.32
Bicycle Shredder	Manual	Plastic	7.95	N$24.73

The final set of recommendations for the processing system consists of the three most profitable options, as highlighted in Table 2. The primary recommendation to Oshakati is for the IWCs to use a solar-powered industrial shredder, similar in type and size to the MOCO Shredding Machine AZ 09F, to shred all plastics and aluminum cans available in the dumpsite to maximize potential profits. The project also recommended two alternative processing systems. The first alternative involves shredding all available plastics and aluminum cans using a generator-powered shredder in the case that implementing a solar panel in the dumpsite is not feasible. The second alternative provides an estimate for shredding only available plastics using the solar-powered shredder if further investigation does not identify a market for processed aluminum in Namibia. For whichever processing system Oshakati choses to implement, the team also recommends that the IWCs have a scale at the dumpsite to weigh their collected and shredded materials so they can monitor their own collection and payments.

The final set of recommendations for the operational strategies included four major organizational aspects of a recycling processing system. The team recommends that the OTC seeks funding for the required processing equipment through a government grant. If the OTC cannot obtain a grant, the town can purchase the equipment using surplus funds in the Oshakati Solid Waste Management budget. Between the years of 2009 and 2014, this surplus averaged at N$680,000, which exceeds the initial costs of the recommended equipment (Mughal et al., 2014). Additionally, these surplus funds can pay for annual maintenance and operational costs. As the entity that oversees the dumpsite, the OTC should be the primary owner of the processing equipment and responsible for maintenance and operational expenses. The OTC should employ a site manager to oversee training programs and supply personal protective equipment for IWCs to ensure safe and efficient operation of processing equipment. This site manager would serve as a liaison between the IWCs and the companies to which they sell to assist in negotiating fair prices. The team recommends that the IWCs, with the help of the site manager, determine the daily operation of the processing equipment and their own internal organizational structure. Both the OTC and IWCs expressed in their interviews that it is important that the IWCs maintain the freedom to organize themselves and control the operational structure of the system. The study recommends that the IWCs pursue Plastic Packaging (PTY) Ltd and Plastic Packaging Polymer Recyclers, two local plastics companies, as potential customers for the shredded plastics.

Through stakeholder interviews, material analyses, and processes analyses this project indicated that a small-scale, solar-powered plastics and aluminum shredding machine funded by the OTC has the potential to increase IWC monthly earnings by up to 330% from their current state. The team foresees that this finding and other subsequent recommendations will serve as a guide for the OTC and Namibia University of Science and Technology (NUST) when designing and implementing a recycling processing system to increase the earnings of the IWCs in Oshakati.

EXECUTIVE SUMMARY BIBLIOGRAPHY

Alsins, A., Sundgren, A., Shooya, R. N. M., & Nashongo, T. N. (2013). Analysis of Qualities and Quantities of Waste and Recyclable in the Namibian Towns. Polytechnic of Namibia, Windhoek, Namibia.

Mughal, M. I., Kalumbu, H., Phillemon, M., & Tulenheimo, R. (2014). *Feasibility study on potential waste between three northern Namibian towns.* Polytechnic of Namibia, Windhoek, Namibia.

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ABBREVIATIONS AND NOTATIONS

CBA: Cost-Benefit Analysis

CoW: City of Windhoek

HDPE: High Density Polyethylene

IWC: Informal Waste Collector

LDPE: Low Density Polyethylene

MRF: Material Recovery Facility

NUST: Namibia University of Science and Technology

PET: Polyethylene Terephthalate

RAD: Rent-A-Drum (PTY) Ltd

SWM: Solid Waste Management Division

WPI: Worcester Polytechnic Institute

CHAPTER 1: INTRODUCTION

Since achieving independence from South Africa in 1990, the Republic of Namibia's population and economy have grown significantly. However, Namibia's infrastructure has not kept pace with the expanding population and urbanization in many regions. Effective waste management systems and regulations in particular are lacking throughout the country. Many towns do not have adequate waste disposal sites, and most towns with waste disposal sites do not manage them effectively. In fact, Kupferburg Landfill in Windhoek is the only disposal site in Namibia recognized by the government as an official landfill with proper sanitary precautions. The lack of waste disposal policies in Namibia has led to an overwhelming volume of waste in dumpsites nationwide.

There are minimal structured recycling systems in Namibia, which leads to a high percentage of recyclable materials accumulating in the dumpsites. Residents dispose of nearly all recyclable materials at dumpsites along with general waste instead of separating and diverting them for reuse. In Namibia, neither the government nor residents treat recycling as a civic duty, but rather as a business opportunity for private companies. These companies, such as Rent-A-Drum (RAD) and Wilco Recycling Company, capitalize on the vast supply of recyclables throughout the country by purchasing or collecting recyclables, packaging them, and selling them to recycling processing plants in South Africa. Throughout Namibia, groups of unemployed individuals, known as informal waste collectors (IWCs), collect and sort recyclable materials from general waste in dumpsites and sell them to the recycling packaging companies to generate a small income for themselves and their families. Not only is this grueling and unpleasant work, but working in dumpsites continually exposes these workers to dangerous pathogens and toxic chemicals. Additionally, IWCs earn very little money for their efforts. Neither the town nor the private recycling packaging companies formally employ IWCs, therefore the national minimum wage for general construction laborers does not apply to them, leaving many of these individuals in poverty.

Namibia University of Science and Technology (NUST) has sponsored several projects that are working towards improving the recycling system and working conditions for IWCs in Namibia. The latest of these projects was the Recycle by Bicycle project series, which NUST conducted in Windhoek, the capital city, and in Oshakati, a major town in Northern Namibia.

These projects studied potential waste collection strategies that removed IWCs from the dumpsites and helped them collect more recyclables directly from households to improve their collection rates and livelihoods. The project prototype consisted of a bicycle with an attached trailer for recyclable collection. IWCs rode this bicycle through residential communities and collected recyclables from roadside waste bins, reducing the need for workers to scavenge through dumpsites to recover recyclable materials. The initial Recycle by Bicycle trials demonstrated an increased income for bicycling IWCs and a decreased exposure to the harmful dumpsite environment. The Recycle by Bicycle pilot test in Oshakati projected an increase in income for IWCs by N$0.75 per hour, a 71% increase to their estimated dumpsite collection earnings (Haukena, 2016).

Oshakati IWCs' earnings are low primarily because of the low purchase prices for recyclable materials set by the private recycling packaging companies in the region. These packaging companies bale and transport the recyclables they purchase to processing plants in South Africa. These materials must be transported to South Africa due to the lack of recycling processing facilities in Namibia. The costs that the packaging companies incur from this transportation stage reduce the purchase prices they offer IWCs for materials. A second restricting factor for the purchase prices is the tendency of businesses to exploit cheap labor in order to maximize profits. Due to the structure of the informal system, IWCs are not in a position to negotiate prices or customers for unprocessed recyclables. By adding value to the recyclables they collect, IWCs could appeal to new markets, and with the help of the OTC, the IWCs could negotiate fair prices. The primary method for increasing the value of recycled materials is by processing recyclables into a more useful form for industry. Simple processing performed at the dumpsite by Oshakati IWCs could add value to the recyclables they sell and result in increased earnings for IWCs.

This project aimed to improve the earnings and livelihoods of informal waste collectors in Oshakati by recommending a recycling processing system to add value to their collected materials. WPI students, in collaboration with students and faculty at NUST, traveled to Oshakati to gain an understanding of the current recycling system and to identify requirements for a local recycling processing system. The project team conducted interviews and held open discussions with IWCs and other key stakeholders in Oshakati and the neighboring communities. Using ideas from the team's preliminary research and input from stakeholders, the team identified several potential processing systems and business models that could effectively add value to the recyclables and improve earnings for IWCs. The team then conducted a cost-benefit analysis to compare these systems and ultimately selected a system for Oshakati that aligns with the project goals and satisfied the stakeholder needs. The final recommendations for the town of Oshakati included the proposed recycling process and operational strategies describing how this system could be organized and implemented in the region.

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CHAPTER 2: BACKGROUND

Unemployment and inefficient waste management are two challenges that face the country of Namibia and more specifically the northern town of Oshakati. This chapter begins with a brief discussion of the history and society of Oshakati. Section 2.2 explains the local waste management challenges and the informal waste collectors' role in the waste management system. This section also provides information regarding the harmful health and environmental effects of the current waste management system. Section 2.3 presents recycling as a promising solution to Oshakati's waste management problem, and reviews past initiatives to improve the profitability of recycling in the region. Finally, Section 2.4 analyzes some potential recycling techniques and processes that could help increase earnings for Informal Waste Collectors (IWCs) in Oshakati.

2.1 Introduction to the Region

The Republic of Namibia lies on the southwestern coast of Africa, as shown in Figure 2. The nation was under rule for 106 years, first by Germany and then by South Africa, until Namibia gained independence in 1990. Windhoek, the capital of Namibia, is the largest city in the country with a population over 325,000 (Namibia Statistics Agency, 2012b). Since gaining independence, Namibia has grown economically and, as of 2015, has one of the highest GDPs per capita in Africa at N$60,756.41 (The World Bank, 2017). However, this wealth is not evenly distributed; approximately two-thirds of the population is left in poverty (Green, 2016). In 2011, the Namibia Statistics Agency (2012b) established the national poverty line at N$377.96 monthly income for "poor," at N$277.54 monthly income for the "severely poor," and at N$204.05 monthly income for the "food poverty line," as shown in Table 3. While widespread poverty is not as prominent in more urbanized areas such as Windhoek, it is a significant challenge in many less developed regions.

Figure 2: Map of Namibia (Encyclopedia Britannica, 1998)

Table 3: National Poverty Lines in Namibia in Namibian Dollars per Month (Namibia Statistics Agency, 2011)

Poverty line	1993/1994	2003/2004	2009/2010
Food poverty line	76.77	127.15	204.05
Lower bound poverty line: "severely poor"	106.78	184.56	277.54
Upper bound poverty line: "poor"	145.88	262.45	377.96

2.1.1 Oshana Province

The Oshana Province is a diverse region located in Northern Namibia, shown in Figure 3. Oshana is home to more businesses than any other region in Namibia. The urban expansion of the region offers economic promise, but the development of infrastructure and employment opportunities is not keeping pace with population growth. The three largest towns where most businesses are located in Oshana are Ondangwa, Ongwediva, and Oshakati. The largest of these three is Oshakati, the capital of the Oshana Province. Figure 3 shows the locations of these three towns relative to one another.

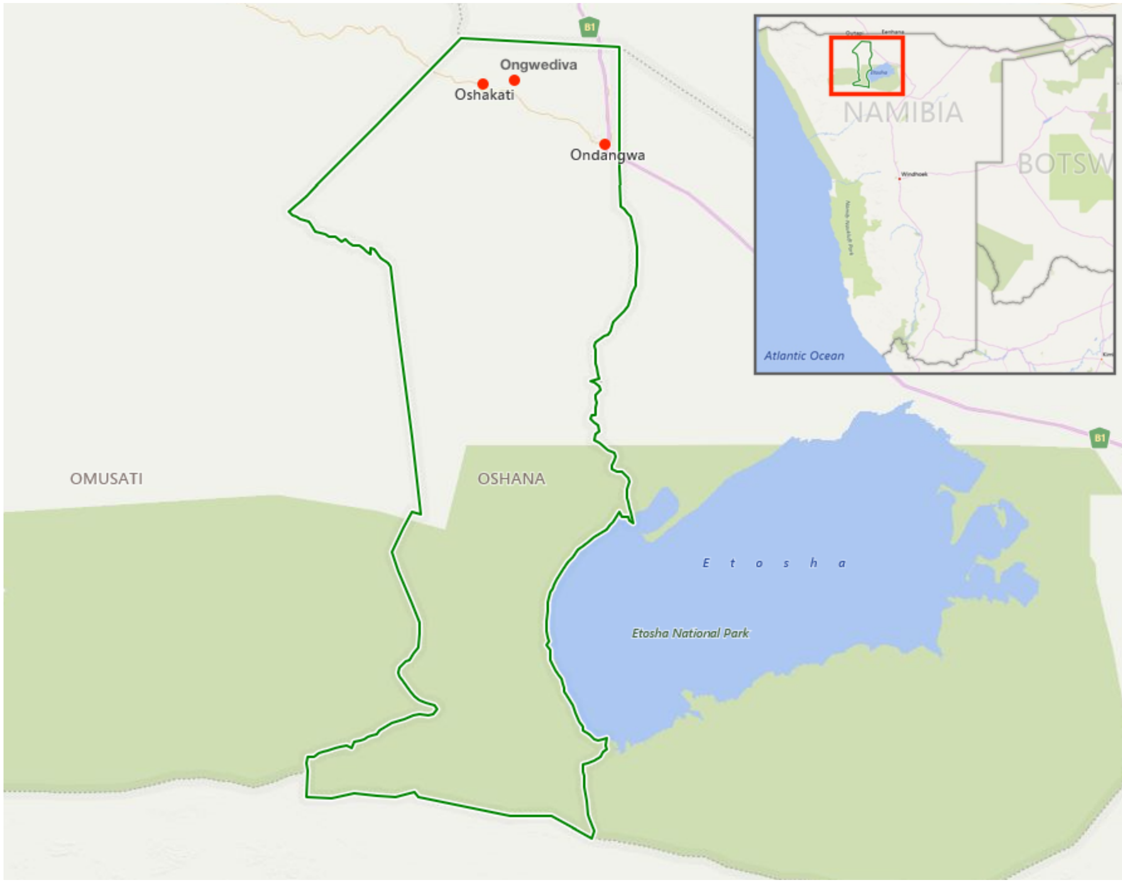


Figure 3: Map of Oshana Province (modified from Bing Maps, 2017)

2.1.2 Oshakati

Oshakati is the hub of Northern Namibia and the fifth largest urban settlement in the country (Namibia Statistics Agency, 2012b). Located 65 kilometers south of the Angolan border, Oshakati has developed into a major international trade hub. South African rule officially established the town of Oshakati in July 1966 as an operations base for the South African Defense Force. Oshakati is part of the area previously known as Ovamboland, home to the Owambo people, and the local language of the region is Oshiwambo. The Namibia Statistics Agency's 2011 census reported a population of approximately 37,000, with a 0.9% annual growth rate in Oshakati (Namibia Statistics Agency, 2012b). It is one of the only areas of Northern Namibia with an established trading system.

In the years before Namibia's independence, white South African soldiers moved into Oshakati East to enforce the South African government's apartheid policies. These policies restricted Oshakati East to a white-only township, which became home to many South African soldiers. Oshakati West became a formal black township, and as the population grew, the poorest settlers were left to erect iron shacks and dwellings in informal settlements on the outskirts of town. By the time of Namibia's independence in 1990, Oshakati's population was approximately 21,600 people, and about 85% of the population lived in these informal settlements (Tvedten, 2011). The majority of people who migrated to Oshakati in the early 1990s searched for low-paid unskilled jobs or self-employment in the informal economy (Hangula, 1993). These early town characteristics prevail today, as 11 informal settlements still hold a significant portion of the population in Oshakati.

2.2 Waste Management in Oshakati

The Environmental Management Act of 2007 defines "waste" in Namibia as "any matter whether gaseous, solid or liquid or any combination thereof, which is from time to time listed by the Minister by notice in the Gazette or by regulation as an undesirable or superfluous by-product, emission, residue or a remainder of any process or activity." Waste management is the system of regulations and processes that facilitates waste disposal and recovery (Hasheela, 2009). A robust waste management strategy is vital to the health, safety, and happiness of a community; the inadequate removal and disposal of waste has unpleasant and even dangerous repercussions, described in Section 2.2.3. Most towns and communities in Namibia, including Oshakati, do not have adequate waste management regulations or infrastructure (Hasheela, 2009).

2.2.1 Waste Collection in Oshakati

The Oshakati Town Council (OTC) has a limited role in the town's current waste collection and management system. Table 4 shows that the town allocated N$4.2 million to the solid waste management program during the 2013-2014 fiscal year (Mughal et al., 2014). This equates to approximately N$114 per capita per year. This is less than one quarter of Windhoek's allocation for solid waste management, which is approximately N$460 per capita (Haidula, 2016). Additionally, in recent years, Oshakati did not use all of its budgeted funds for solid waste management, leaving an average annual surplus of about N$680,000 (Mughal et al., 2014). This low spending is evidence that the OTC provides few organizational and monetary resources to the formal waste collection and management system, thus the local system lacks sufficient infrastructure and efficiency.

Table 4: Oshakati Town waste management budget in millions of Namibian dollars (Mughal et al., 2014)

Year	Allocated Budget	Expenditure	Surplus funds
2009-2010	3.6	3	0.6
2010-2011	5	3.8	1.2
2011-2012	4.3	3.6	0.6
2012-2013	4.4	3.7	0.7
2013-2014	4.2	3.8	0.3

Private waste collection accounts for nearly half of the money the town council spends on the waste management program (Mughal et al., 2014). The town of Oshakati hires 11 private corporations to collect municipal waste from households and deliver it to the town dumpsite (Yang & Peuya, 2015). Residents leave their waste in plastic bags or waste bins on the streets in front of their homes; there are very few government-supplied waste disposal containers designated for resident use (Mughal et al., 2014). Private waste companies use large trucks to collect curbside household waste throughout the week. However, it is not uncommon for the private companies to skip one or more collections without notice (Haukena, 2017). About 90% of formal settlement households have waste bins, while only 50% of informal households possess these bins (Yang & Peuya, 2015). Waste collection companies deliver waste to the Oshakati dumpsite, pictured in Figure 4. Residents and small, private waste collectors may also drop off waste at the dumpsite.

Figure 4: Oshakati dumpsite (Mughal, 2014)

The Oshakati dumpsite covers an area of approximately 62,000 square meters, and is located four kilometers west of the town center, as shown in Figure 5. The dumpsite is "chaotic" and disorganized with 11 separate town-contracted companies making daily deliveries, in addition to the many individuals that drop off small loads of waste. The dumpsite employees provide minimal direction or regulation for where to dump the waste. As a result, waste often builds up at the front of the site near the entrance, blocking access to the rest of the grounds. This requires frequent burning of waste (pictured in Figure 6) to create space for additional waste deliveries (Alsins et al., 2013). When the Alsins et al. research team visited the dumpsite in 2013, they noted the insufficient management and described the operation as "chaotic." Oshakati residents agree, with 87% of surveyed dumpsite visitors describing the conditions as "bad or very bad," (Mughal et al., 2014).

Figure 5: Location of dumpsite relative to Oshakati, outlined in red (modified from Google Maps, 2017)

Figure 6: Burning waste in the Oshakati dumpsite (Alsins et al., 2013)

In addition to the disorganized atmosphere caused by frequent deliveries, there is also a constant removal of waste from the dumpsite. Approximately 30 individuals operate as informal waste collectors (IWCs) at the Oshakati dumpsite (Haukena, 2017). These individuals, nearly all women, sort through the waste, collecting recyclable materials to sell to private recycling companies. Figure 7 depicts one such IWC at work in the Oshakati dumpsite. The Oshakati government has an official register of collectors operating at the town dumpsite, although not all of the IWCs currently working are registered (Yang & Peuya, 2015). Registering is part of a policy by the Oshakati Town Council that sets minimal regulations regarding IWCs, prohibiting pregnant women from working within the dumpsite, and giving IWCs the exclusive rights to sell whatever they collect (Haukena, 2017). Rent-A-Drum (PTY) Ltd (RAD) and Wilco Recycling Company are two private corporations that purchase recyclable materials from IWCs and sell the materials to recycling processing companies in South Africa. Both companies pay the IWCs a set price per kilogram for each type of recyclable material. An IWC operating at the Oshakati dumpsite and selling materials to either RAD or Wilco earns an average of N$1.06 per hour of labor, according estimates made in a recent study by Haukena (2017). For an IWC working eight hours a day, five days a week, this amounts to an estimated monthly income of approximately N$190. This preliminary data shows that Oshakati's IWC earnings are 3% of the national average monthly income of N$6,802, as stated in the Namibia Labour Force Survey 2014 Report (Namibia Statistics Agency, 2015). Based on the Namibia Statistics Agency's *Poverty Dynamics in Namibia Report*, these earnings are 49.7% below the national upper bound poverty line, and 31.5% below the lower bound poverty line (Namibia Statistics Agency, 2012a). Thus, the Namibian government classifies IWCs operating in the Oshakati dumpsite as "severely poor." IWCs are not part of the formal economy, therefore the national minimum wage for general construction laborers of N$16.04 per hour does not apply to them (Ministry of Labor, 2015).

Figure 7: Informal waste collector working in the Oshakati dumpsite (Haukena, 2017)

2.2.2 Causes of Waste Management Issues in Oshakati

The challenges preventing Oshakati from achieving efficient waste management practices fall into two main categories: minimal waste management education and the lack of a local waste management policy. These issues combined account for the widespread notion in Namibia that waste is profitless and cannot be used as a way to boost the economy (Mughal et al., 2014). Many residents of Oshakati are uneducated about waste management and have limited understanding of the environmental and health concerns associated with improper waste disposal. They are unaware of the benefits related to a proper waste management system and see little value in waste and waste management occupations (Yang & Peuya, 2015). Of those living in informal settlements, 61% did not receive education past the 4^{th} grade (Tvedten & Nangulah, 1999). Furthermore, in a 2014 survey, only 12% of Oshakati residents reported being formally educated about waste management, whereas the rest of the survey participants acknowledged that they had never been educated about hazardous waste, waste sorting, or the benefits of recycling (Mughal et al., 2014). The widespread lack of understanding about safe waste management practices results in citizens leaving waste on the side of the road, in parking lots, and other public places.

The current waste management policy of Oshakati is the Environmental Management Act of 2007, which provides guidelines to preventing waste issues but does not give details on proper execution of waste practices. Article 4 of the 2007 Act states that: "A person may not discard waste or dispose of it in any manner, except: At a disposal site declared or approved by the Minister," (Office of the Prime Minister, 2007). Section 5 goes on to state that a person shall be fined for not adhering to Article 4. This Act tried to give structure to a waste management solution, but the minister wrote no further policy to approve sites for disposal.

2.2.3 Health and Environmental Concerns of Current Waste Management System

The lack of sanitation and efficient waste management leads to various environmental and health repercussions. The working conditions in dumpsites are dangerous and compromise IWCs' health. Oshakati town employees burn waste frequently to clear room in the dumpsite, releasing harmful chemicals and bacterial contaminants into the air and soil. IWCs' skin and lungs are exposed to high levels of toxins as they work in the dumpsite. IWCs have minimal access to protective clothing and equipment when working in dumpsites, which can lead to injury or infection (Haukena, 2017). The poor working conditions also affect the mental health of IWCs as performing labor-intensive work for such low pay has shown to cause stress and lead to mental health issues (Moreno-Sanchez & Maldonado, 2006).

2.3 Recycling as a Waste Management Solution

Recycling is a method of managing waste in an efficient, sustainable manner. Recycling reduces the amount of waste being disposed in dumpsites while also recovering monetary value from waste materials (Hasheela, 2009). Figure 8 depicts the flow of waste materials in Oshakati. Oshakati residents generate waste and deposit it to the local dumpsite or to roadside containers. The town brings waste from roadside containers to the dumpsite. From the dumpsite, waste materials can follow one of two paths. In the first path, town waste management employees burn material to reduce the volume of waste in the dumpsite. In the second path, IWCs operating in the dumpsite recover and sort as many recyclable materials as possible to divert them from the burning disposal method. IWCs then sell the collected materials to the recycling packaging companies, RAD and Wilco. According to the Recycle Namibia Forum (2014), an organization dedicated to promoting recycling throughout the country, a typical Namibian household can potentially divert 60% to 80% of their total waste from the dumpsite through recycling. The more developed areas have local recycling facilities, while less developed areas may not have this resource and they must burn excess waste material.

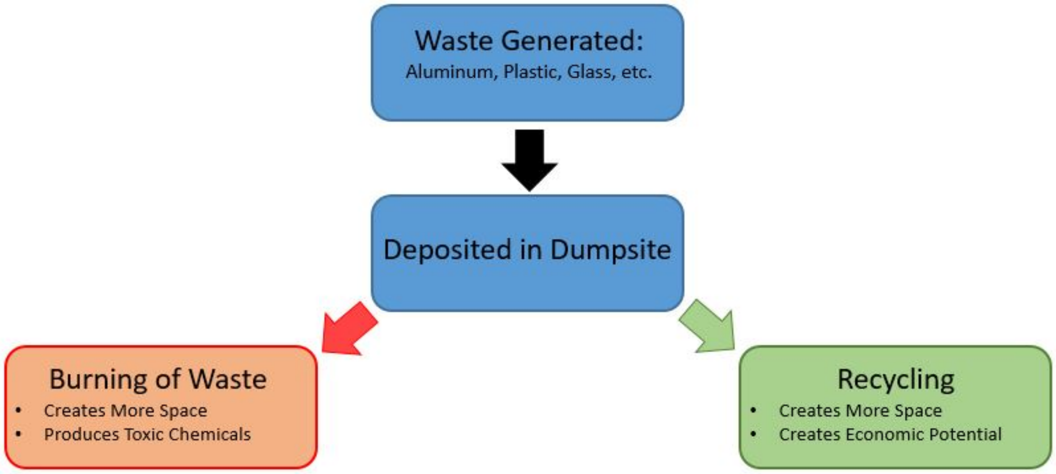


Figure 8: Flow chart of recyclable waste in Oshakati

2.3.1 Case Study: Windhoek Recycling Initiatives

Windhoek, the largest city in Namibia, has the most advanced recycling program in the country. Windhoek's Solid Waste Management Policy (SWM Policy), implemented in 2010, focuses on minimizing the negative effects of waste. The objectives set forth in the policy include Waste Minimization, Health Care Risk Waste Management Strategy & Plan, Community Participation in Waste Management Activities, and Research and Development (City of Windhoek, 2016).

The first objective, Waste Minimization, is the main focus of Windhoek's recycling program. The City of Windhoek encourages citizens to use less wasteful materials and to recycle whenever possible. Figure 9 depicts the results from a 2009 study on the composition of waste in Windhoek's landfill, which reveals that about 45% of the waste entering the city landfill is recyclable materials (Hasheela, 2009). Recycling these types of materials can reduce the amount of waste accumulating in the landfill and therefore increase the lifespan of the landfill. To facilitate recycling collection in Windhoek, RAD sells bags to citizens to fill with recyclable waste. Waste management workers then collect the filled bags from households and transport the materials to RAD to begin the recycling process (Haukena, 2017).

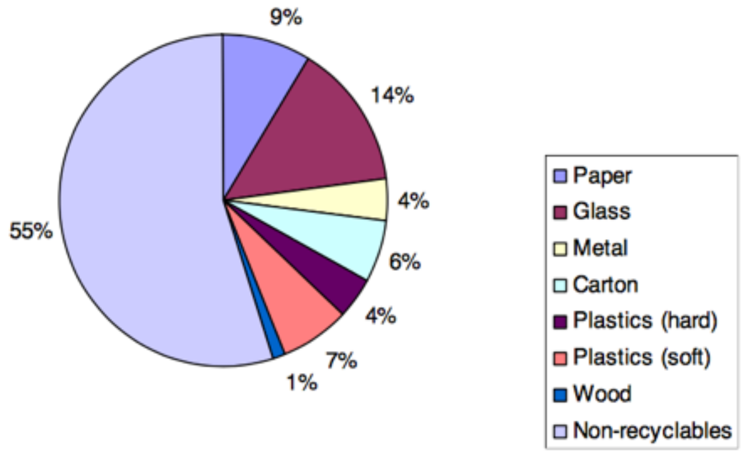


Figure 9: Recycling waste streams in Windhoek (Hasheela, 2009)

In 2014, students from Worcester Polytechnic Institute (WPI) collaborated with Namibia University of Science and Technology (NUST) to develop a bicycle with an attached cart for transporting recyclables in Windhoek. The goal was to provide an efficient method for recycling collection that would integrate informal waste pickers into the formal Windhoek recycling system (Jacobsen et al., 2014). Figure 10 shows the prototype bicycle trailer developed by the students. The trailer has a 100-kilogram capacity, and costs N$2482.60 to manufacture (Jacobsen et al., 2014).

Figure 10: Completed recycle by bicycle prototype (Jacobsen et al., 2014)

The 2014 project team established pilot routes throughout Windhoek and IWCs tested trial rounds. On average, each bicyclist collected N$8.46 of recyclables per hour (Jacobsen et al., 2014). The collection rate represents an increase of N$0.30 from the income an IWC was able to earn during one hour of collecting from the local landfill. Although these results were promising, the hilly landscape of Windhoek inhibited the growth of the initiative. As a result, NUST sponsored additional Recycle by Bicycle projects to apply the idea to other Namibian settlements, including Walvis Bay and Oshakati.

2.3.2 Recycling Potential in Oshakati

Due to the lack of a convenient recycling system, all municipal waste in Oshakati is currently sent to the town dumpsite. This equates to an estimated 143,600 kilograms of waste per month (Haukena, 2017). 49% of the total waste delivered to the dumpsite is recyclable (Alsins et al., 2013). Figure 11 provides an estimated weight of total recyclable materials that are currently accumulating in the Oshakati dumpsite every week. These materials represent untapped economic potential.

Material	Amount Delivered per Week (kg)
Cardboard	5345
Plastics	4255
Paper	4178
Glass	2052
Metals	1062
Tetrapak	383
Styrofoam	290
Non-Recyclables	18332

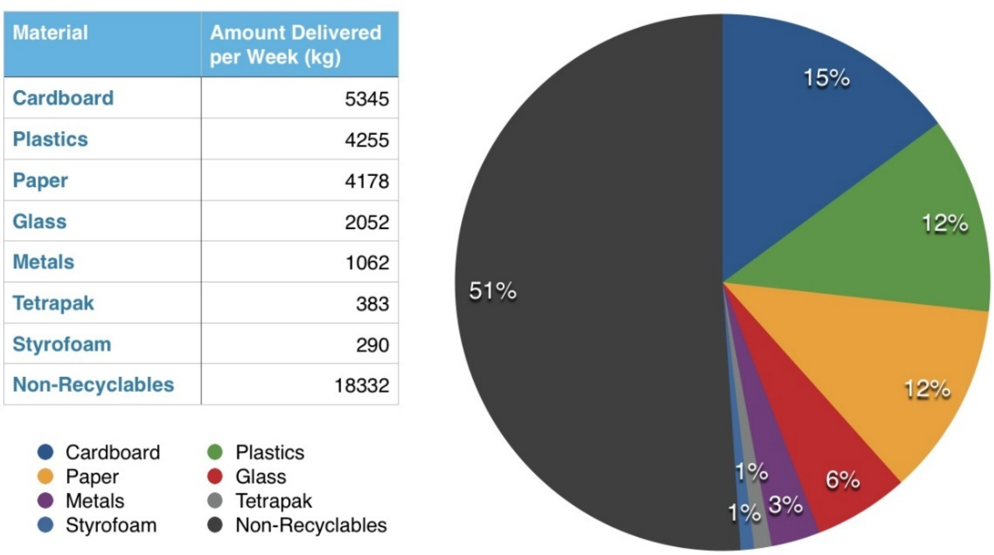


Figure 11: Materials entering the Oshakati dumpsite each week (adapted from Alsins et al., 2013)

IWCs and recycling companies work to recover as much of these materials as possible. Currently, IWCs extract 5,287 kilograms of material per week from the dumpsite. This equates to approximately 30% of the available recyclable material delivered to the dumpsite (Haukena, 2017). In 2013, a team of students from NUST gathered data about the value and quantities of recyclables discarded in Oshakati. Table 5 uses this data to estimate the total potential value of recyclables in the Oshakati dumpsite, using sale prices set by Wilco Recycling in Northern Namibia (Haukena, 2017). Extrapolating this weekly data over the course of a year indicates that Oshakati's potential gross revenue from recyclables in the Oshakati dumpsite is just over N$289,000 per year (Alsins et al., 2013).

Table 5: Gross Potential Profit by Material per Week (adapted from Alsins et al., 2013)

Material	Amount Disposed per Week (kg)	Value per kg paid by WILCO (N$)	Gross Potential Profit per Week (N$)
Plastics	4255	0.4	1702.00
Paper	4178	0.35	1462.30
Metals, Aluminum	385	2.5	962.50
Cardboard	5345	0.15	801.75
Metals, Other	677	0.5	338.50
Glass	2052	0.16	328.32
Tetrapak	383	0.15	57.45
TOTAL			5652.82

2.3.3 Recycle by Bicycle in Oshakati

Two years after the WPI students conducted the Recycle by Bicycle project in Windhoek, students at NUST studied how the Town of Oshakati could adopt this strategy. The NUST team implemented the Recycle by Bicycle system in Oshakati for a trial period, which demonstrated a N$0.75 pay increase for IWCs, from N$1.06 per hour for an IWC operating in a dumpsite to N$1.81 per hour for an IWC using the bicycle trailer to collect from households. This increase is greater than the pay increase observed in Windhoek in the similar pilot program mentioned in Section 2.3.1 (Haukena, 2017).

Following this trial period in 2016, NUST student Martha Haukena conducted interviews at 100 homes throughout Oshakati to gauge public interest in the project and its objectives. She found that 97% of surveyed citizens supported a Recycle by Bicycle initiative (Haukena, 2017). Haukena also found that the Oshakati Town Council gives full support to the Recycle by Bicycle initiative due to its potential to create jobs. Haukena's evaluation of the Recycle by Bicycle project in Oshakati recommends further study to "[r]esearch the possibility of establishing a small-scale glass recycling plant in Oshakati." She based her recommendation on the abundance of glass waste in the Oshakati region.

2.3.4 Processing Recyclables Collected in Oshakati

Oshakati is one of the few towns in Namibia that has recycling packaging facilities such as RAD and Wilco. These facilities package and prepare recyclable materials for processing plants that convert them into useful products for industry. However, with no large-scale processing facilities in or near Oshakati, local recycling companies must ship the packaged materials out of the country. This is an expensive system that cuts into the profits of recycling packaging companies, and subsequently IWCs. Each month, Oshakati recycling companies send trucks full of recyclable material to South Africa. The transportation alone costs N$24,000 each month (Magen, 2010).

Furthermore, some of these South African processing companies ship industry-ready processed materials back to the Oshana region, where manufacturing companies turn them into finished goods. For example, Plastic Packaging (PTY) Ltd, a plastics manufacturing company in Oshakati, pays to import plastic from suppliers in South Africa to make their container and packaging products. A local processing program that could fully prepare recyclables for industry in Oshakati would minimize transportation costs and potentially increase earnings for IWCs. Additionally, a successful recycling processing system in Oshakati that promotes a cleaner community and improves the livelihoods of IWCs could serve as a model for other developing towns in the Oshana region to adapt.

2.4 Recycling Processes

There is a wide variety of recycling processing technologies currently available around the world. It is important for a local recycling system to use appropriate technology that meets the specific needs of the community. Marc Rogoff, a United States national waste management expert, describes in one of his books, *Solid Waste Recycling and Processing: Planning of Solid Waste Recycling Facilities and Programs*, the factors to consider when designing a recycling system. These include: the size of the community, the types and quantities of recyclables discarded, collection methods, the level of labor available, the desired output product(s) and profit, and the intended purchaser of the materials produced (Rogoff, 2014). A recycling system designer can use these local factors to select the processes and technologies that will best fit the needs and limitations of the community.

2.4.1 Baling Recyclables

Currently in Namibia, recycling companies package and ship materials by compacting them into cubes called bales. This forms the recyclables into a shape convenient for organizing and stacking, and allows the companies to ship larger quantities of material at a time. Nearly all materials that IWCs collect can undergo baling, including plastic, aluminum, steel, cardboard, and paper. This baling process is as follows:

1. Materials are collected and sorted by type;
2. Materials are placed into the baler machine, as shown in Figure 12;
3. The baler mechanically compacts and ties the materials into a cube;
4. The bales are stacked onto trucks and transported for processing.

Figure 12: Rent-A-Drum Oshakati employee using a baler

Balers come in various sizes, ranging from large industrial balers that can compact steel in seconds to small portable balers that pick-up trucks can tow. A large industrial size baler that

Wilco uses in Oshakati costs about N$140,000 while a smaller baler typically costs approximately N$40,000.

2.4.2 Glass Recycling Processes

Glass is an abundant recyclable material in Oshakati, representing about 5.7% of total waste. This equates to about 2,052 kilograms of glass disposed per week (Alsins et al., 2013). The glass recycling process recovers all of the melted glass with no loss of material. Manufacturing glass products with 10% recycled material reduces sulfur dioxide (SO_2) emissions by 10%, carbon dioxide (CO_2) emissions by 17%, and energy use by 1%, as compared to virgin glass processing (Consol Glass Co., 2014).

The glass recycling process requires minimal equipment, and is typically performed as follows:

1. Glass is sorted from other materials and separated by color;
2. Glass of like color have their labels removed and are cleaned of food or glue residue;
3. Glass is crushed to a consistent particle size;
4. Crushed glass, called cullet, is sold to manufacturers to be melted and reprocessed into new materials such as bottles, jars, insulation, or building materials.

The cost associated with this glass recycling process is low compared to recycling processes for other materials. Human labor can perform the sorting and cleaning steps, and glass-crushing machines are simple and inexpensive compared to other industrial processing machines. For example, a CP Manufacturing glass crusher costs N$35,000 and can crush over 3,000 kilograms of glass per hour (CP Manufacturing, 2012).

2.4.3 Metals Recycling Processes

Aluminum and steel are the two most commonly disposed metals in Oshakati. Combined they make up approximately 50% of Oshakati's metal waste (Alsins et al., 2013). The recycling efficiency rate of both aluminum and steel is very high; the recycling process can recover nearly 100% of the material without compromising its mechanical properties. The similarities between aluminum and steel processing often make it practical to perform the two processes, described below, in parallel to one another.

Aluminum

Aluminum is a common material for cans, cookware, housing, and car parts. Manufacturing products from recycled aluminum is more efficient and cleaner than using raw aluminum, consuming 95% less energy and generating 95% less greenhouse gas (International Aluminium Institute et al., 2009). Additionally, the aluminum recycling process does not damage the metal and only results in a 2% metal loss (International Aluminium Institute et al., 2009). Therefore, 98% of aluminum input to the recycling plant leaves the plant as reformed aluminum that possesses the same mechanical properties as virgin metal.

The process to recycle aluminum is as follows (International Aluminium Institute et al., 2009):

1. Aluminum is separated from all other metals using manual labor, magnets, or electrical currents;
2. Aluminum is sheared into small pieces for easier melting;
3. Aluminum is cleaned in a chemical bath to remove ink and other attached materials;
4. Aluminum is melted in a furnace at 750°C. To improve purity, hexachloroethane tablets or other degassers can be added to the molten aluminum to remove gas from the liquid (Total Materia, 2003);
5. Molten aluminum is poured into molding trays to form blocks or ingots;
6. Aluminum ingots are sold to manufacturers to be melted down and formed into new products.

Cost savings from recycling aluminum versus using virgin metals vary by location and process. Aluminum recycling has proven to have an economic advantage over using virgin metals due to the reduction in energy usage. The cost of aluminum melting furnaces ranges from about N$13,130 for a small furnace with the capacity to melt 3 kilograms of aluminum per hour, to N$137, for a larger furnace that has the capacity to melt 100 kilograms of aluminum per hour (Alibaba, 2017; Made in China, 2017). Figure 13 shows an example of an aluminum-processing machine that can block 10,000 kilograms of molten aluminum cans per hour. Determining the appropriate scale of machinery is essential to maximize profits from the aluminum recycling process.

Figure 13: Aluminum processing machine (CP Manufacturing, 2012)

Steel

Steel is a valuable material to recycle due to its versatile reusability. Each ton of steel recycled saves 2.3 cubic meters of dumpsite space and approximately 1.8 barrels of oil compared to producing virgin steel (AZO Materials, 2012). Depending on the size of the melting furnace, prices can range from around N$104,800 to N$262,800 or more (Alibaba, 2017). The following steps summarize the steel recycling process (AZO Materials, 2012):

1. Steel is separated from other materials using manual labor, magnets, or electrical currents;
2. Heavy steel is sheared into smaller pieces using hydraulic machinery or gas or plasma arches;
3. Steel is shredded;
4. Shredded steel is melted in a furnace, such as the one pictured in Figure 14;
5. Molten steel is poured into molds to form blocks;
6. Steel blocks are melted and shaped to form new useful products.

Figure 14: Melting furnace (Dynaform Technologies, Inc.)

2.4.4 Plastic Recycling Processes

Plastics account for about 12% of Oshakati's waste with 4,255 kilograms delivered to the dumpsite weekly (Alsins et al., 2013). There are seven different types of recyclable plastics, the most common of which are Polyethylene Terephthalate (PET), High Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), and Low Density Polyethylene (LDPE). Typically, plastic recycling processes begin as follows:

1. Plastics are sorted by type into separate processing streams;
2. Plastics are cleaned with chemicals from residues and contaminants;
3. Plastics are compressed into blocks;
4. Blocks are ground or cut into chips;
5. Chipped plastic can undergo a variety of further processing, such as pelletizing or shredding to create useful materials for industry;
6. Recycled plastic materials are melted and molded into new products.

The two general quality levels of recycled plastics are food grade and non-food grade. Food grade plastics are higher in quality and require an additional sanitation step during processing. Food-grade plastics are the only acceptable material for the plastic packaging of edible products. Non-food grade plastics are acceptable for products that will not come into contact with any edible goods. The type of plastic and manufacturing application used determines the quality grade of a recycled plastic steam.

Pelletizing is one of the most common techniques for preparing both food grade and non-food grade recycled plastics for industry. This process applies to both PET and HDPE plastics, which are very common in Oshakati in the form of plastic bags, bottles, and milk and water jugs (Hasheela, 2009). To produce plastic pellets, a pelletizer machine softens chipped plastic with heat, and extrudes it through a die to form plastic strands, which the machine immediately cools and chops into small pellets (Van Den Berg, 2009). Typically, a water spray quickly cools and hardens the plastic strands before a motorized blade on the pelletizer chops the strands into a consistent pellet shape and size. In 2015, Marco Adame, the founder of Ak Inovex, developed a technology that can process 90% of plastic types into pellets without using water (Investigación y Desarrollo, 2015). This breakthrough in the technology significantly reduces the required resources, energy, and cost for the pelletizing process.

Manufacturers that purchase these recycled pellets melt and shape them into new useful products. The pellet form is particularly useful for manufacturing because small pellets melt easily and consistently, which is ideal for plastic extrusion manufacturing. Figure 15 shows a complete plastic recycling process, which waste collectors initiate when they separate plastics from other waste materials.

Figure 15: Plastic recycling process (adapted from Haarman, 2015)

Various developing countries around the world use recycled plastic processing to promote economic and environmental sustainability and employment opportunities. For example, the town of Ahmedabad, India has an informal waste collection system similar to that of Oshakati. IWCs in Ahmedabad operate a plastic pelletizing process. The 39 waste collectors collect around 1,800 kilograms of raw plastic material and produce about 1,200 kilograms of plastic pellets per day using the pelletizer machine depicted in Figure 16 (Vasave, 2013). The average pelletizer machine costs approximately N$105,030 (Van Den Berg, 2009). Pelletizing is a simple and efficient technique for recycling plastics for significant monetary returns (Vasave, 2013).

Figure 16: Example of pelletizer machine in India (Van Den Berg, 2009)

2.4.5 Paper Product Recycling Process

Paper products, such as newspapers, books, and cardboard, account for approximately 16% of the total waste composition in Oshakati (Alsins et al., 2013). Unfortunately, water and other contaminants can easily damage paper products, resulting in impurities in the recycled papers and requiring additional treatment steps to achieve a high-quality product (European Paper & Packaging Industries, 2017). Therefore, the initial disposal, collection, and sorting methods limit the attainable product quality and resulting profits from paper recycling.

The standard paper product recycling process includes the following (Bajpai, 2013):

1. Paper products are collected and separated based on type into individual streams;
2. Paper products are combined with water and mixed together to form a pulp, and contaminants such as staples and paper clips are removed using filters;
3. The pulp is screened to separate fibers from one another;
4. The pulp may undergo one or more deinking stage, in which the pulp is cleaned with a chemical solution that separates ink particles from the fibers;
5. The pulp can be formed and dried into various recycled paper products by manufacturers.

Deinking is a supplementary, but not essential, step in the recycling process for paper when producing virgin papers from tree fibers. The pulp undergoes repeated cleaning and deinking stages until it is purity level is sufficient for the desired level of processing. This requires additional chemical, water, and energy resources as compared to the manufacturing of virgin papers. Additionally, the cleaning process filters out some of the paper fibers, resulting in a lower material yield. However, the process does not include the deinking when producing low or medium grade recycled paper products for applications in which consistent color and texture is not necessary (Bajpai, 2013).

2.5 Project Stakeholders

Any individuals, companies, or entities involved in the current Oshakati recycling system are stakeholders of this project. Figure 17 illustrates the flow of materials and money in the waste management system of Oshakati, highlighting the stakeholder groups. Each stakeholder group has different motivations and opinions with respect to the local recycling system. It was important for this investigation to understand and consider all of these viewpoints when recommending changes to the system. The following sections introduce each of the key stakeholder groups for this project. Since the project does not intend to change the current waste disposal structure in Oshakati, the final recommendations will have minimal impact on Oshakati residents and the private waste collection companies that bring household waste to the dumpsite. Thus the team does not consider these groups to be major stakeholders in the project. The project instead focuses on the stakeholder groups that work directly with recyclables.

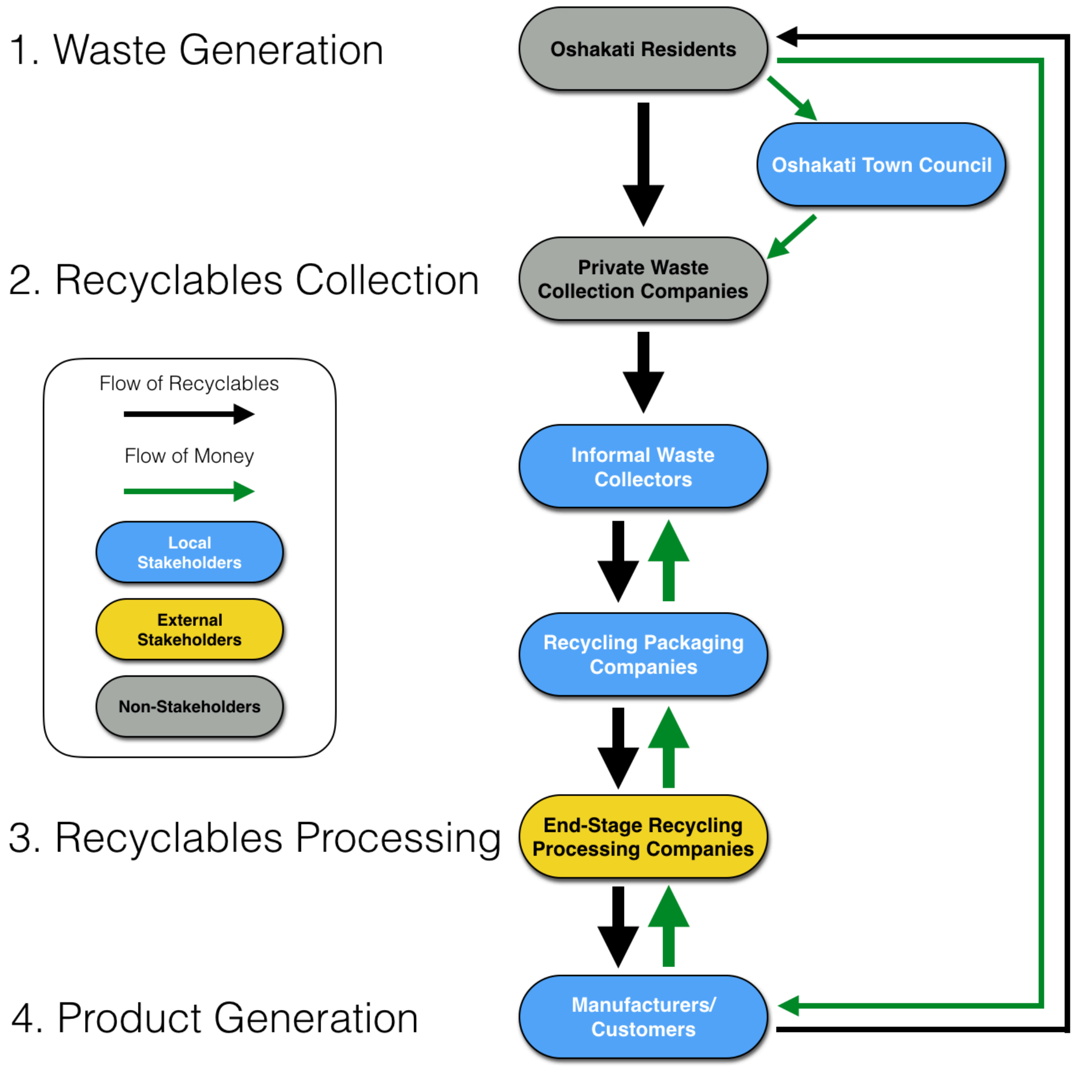


Figure 17: Flow of recyclables and money in the Oshakati recycling system

2.5.1 Informal Waste Collectors in Oshakati

The IWCs operating in the Oshakati dumpsite are the primary intended beneficiaries of this project, and therefore are the primary stakeholders. In the current system in Oshakati, IWCs initiate the recycling process by collecting and sorting recyclable materials from the dumpsite and selling them to private recycling packaging companies. As Section 2.2.1 describes, these individuals earn very little money for their efforts. This project intends to enhance the quality of life for IWCs by improving their working conditions and income. IWCs in Oshakati will offer the most valuable insight regarding challenges in the current system as well as suggestions for potential improvements. The success of any improvements that this project recommends depends on the support and involvement of the Oshakati IWCs.

2.5.2 Oshakati Town Council

The local governing body in Oshakati is the Oshakati Town Council (OTC). The OTC determines the local waste management laws and has authority over the local dumpsite and its operations. Any significant change to the local waste management or recycling system requires the approval of the OTC. The primary motivations of the OTC, with respect to recycling and waste management, are to modernize local systems and to promote environmental and economic sustainability in Oshakati. They can offer input about the requirements and restrictions for a restructured recycling system in Oshakati that will benefit IWCs as well as the town as a whole. The team must consider their views and suggestions, and also seek their support and active involvement in this initiative.

2.5.3 Recycling Packaging Companies

The two packaging companies that operate in Oshakati are RAD and Wilco. These companies collect recyclables directly from households and businesses and also purchase recyclables from IWCs operating in the Oshakati, Ongwediva, and Ondangwa dumpsites. Both companies currently bale and package the materials at their local facilities for transportation to end-stage processing facilities in South Africa. Since the government does not sponsor any official recycling program, these companies facilitate the only means for recycling in the region.

Both companies aim to maximize their own profits, which will influence their willingness to support the project. These companies could view a new system as either an opportunity to expand their current operations and profits, or as a competitive threat to their current business. Currently, RAD and Wilco monopolize the recycling system in Oshakati and the surrounding region. Therefore, their support is important to the success of the project. In order to avoid resistance from these companies, the team must consider their interests and roles in the community when developing recommendations for a recycling processing system in Oshakati.

2.5.4 End-Stage Recycling Processing Companies

RAD and Wilco sell and transport their baled materials to processing companies in South Africa. These companies transform the baled materials into manufacturing-ready materials or into final products. One company, Consol Glass purchases crushed glass from RAD and Wilco and melts it to form into jars and other glass products. Mpact Recycling purchases PET, LDPE, and HDPE plastic bales from RAD and Wilco and produces plastic packaging products. Both Consol Glass and Mpact Recycling sell their packaging products to food manufacturers and other industries in Namibia as well as other countries. The processing techniques used by Consol Glass, Mpact Recycling, and other South African processing companies, add value to the baled recycled materials they purchase from packaging companies. Adding value to the materials collected by IWCs in Oshakati is a goal of this project, thus these recycling processing companies can serve as examples of successful recycling business structures.

2.5.5 Manufacturers/Potential Customers

This category of stakeholders includes any manufacturing company that may be interested in purchasing processed recyclable materials from a local recycling system. Ideally, these manufacturers will be located in Oshakati or the Oshana region, to stimulate the local economy and to minimize transportation costs. One example of a potential customer is Plastic Packaging in Oshakati, introduced in Section 2.3.4. In order for a local recycling processing system to be successful, there must be a sustainable market to which IWCs can sell their processed materials. Therefore, the project must investigate potential customers and their requirements for material suppliers, and apply this information when developing processing recommendations for Oshakati.

2.5.6 Informal Waste Collectors in Surrounding Communities

In addition to improving the earnings of Oshakati IWCs, a modified recycling system in Oshakati could serve as a model to benefit IWCs in other Oshana communities. In order for this project's recommendation to succeed as a model for other towns, it must consider the similarities and differences in recycling structures and IWC interests across several Oshana communities. Ondangwa and Ongwediva are two nearby towns with similar recycling structures to that of Oshakati, and are the most likely to adapt such a model. Therefore, the IWCs in these two towns will represent this stakeholder group.

2.6 Summary

Oshakati's population and economic growth has caused a rapid increase in waste production. Without a formal recycling system, the town is overfilling the local dumpsite. IWCs have found a way to generate income by searching through the town's dumpsite and collecting recyclables that they sell to recycling companies at extremely low prices. IWCs may be able to increase their earnings by performing simple recycling processes that transform materials into more valuable forms for industry. There is a wide variety of recycling processing techniques that add value to the materials IWCs collect, ranging from simple crushing or baling of materials to further processing of glasses, metals, and plastics. By establishing recyclables processing in Oshakati, IWCs could generate more income by reducing the need to ship recyclables to South Africa for processing.

CHAPTER 3: METHODOLOGY

The project goal was to increase the earnings of informal waste collectors in Oshakati, Namibia by recommending a recycling processing system to add value to their collected materials. The scope of this project limited the proposal of a "recycling processing system" to the following two elements:

1. Process(es): The technique for preparing a particular recyclable material for industry, and the associated resources and equipment;
2. Operational Strategies: The type of organization that owns and operates the processing equipment or facility, and the method that the organization employs to integrate the informal waste collectors into this system.

The ultimate project deliverable was a recommendation of the best combination of these elements that eliminates unnecessary costs and provides increased earnings and livelihoods for Oshakati IWCs. The following objectives guided the project:

Objective 1: To observe existing recycling systems and interview stakeholders;

Objective 2: To evaluate potential strategies for adding value to the recyclable materials;

Objective 3: To prepare recommendations for a recycling processing system in Oshakati.

Figure 18 shows how the team progressed through these three objectives. The following sections describe the methods used to complete each objective.

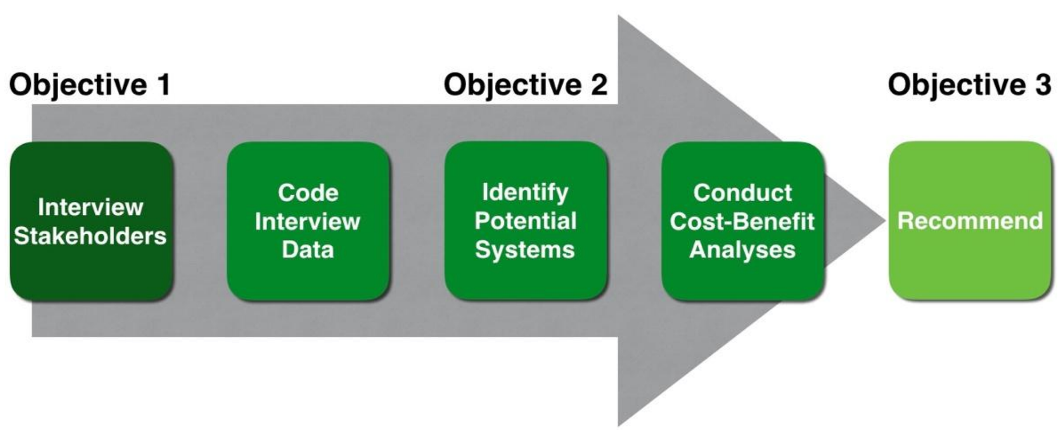


Figure 18: Methodology flowchart

The timeframe for this project was 12 January 2017 through 6 May 2017. The project was in collaboration with Namibia University of Science and Technology, Worcester Polytechnic Institute, and major stakeholders in Oshakati, Namibia. It was a continuation of a series of NUST Recycle by Bicycle projects that investigated recycling as a solution to the waste management problems in various Namibian towns. For one week the team interviewed informal waste collectors, recycling companies, and town councils in the Oshana region to understand the current recycling system and investigate opportunities for improvement through recycling processing.

3.1 Objective 1: To Observe Existing Recycling Systems and Interview Stakeholders

Understanding the current waste management and recycling practices and technologies in Namibia was a key first step to the project. Before proposing changes, it was important to fully understand the existing systems, which provided a foundation for the restructured recycling system. This first phase of the project assessed the available resources, perspectives, and requirements of stakeholders. Before traveling to the Oshana region, the team assessed the current systems and stakeholders in Windhoek to gain a baseline understanding of waste management practices in Namibia. In the Oshana region, the team interviewed the major stakeholders to gauge interest in processing techniques and observe the current recycling system challenges. Table 6 displays each stakeholder interviewed, the date of the interview, and the interview type.

Table 6: List of stakeholder interviews

Stakeholder Interviewed	Date of Interview	Interview Type
Kupferberg Landfill Contractor	22 March 2017	Semi-Structured Interview
Ongwediva IWCs	28 March 2017	Group Semi-Structured Interview
David Henok, Oshakati Rent-A-Drum Branch Supervisor	28 March 2017	Semi-Structured Interview
Ondangwa IWCs	29 March 2017	Group Semi-Structured Interview
Willem Coetzee, Wilco Recycling Owner	29 March 2017	Semi-Structured Interview
Oshakati Town Council	30 March 2017	Presentation and Open Discussion
Oshakati IWCs	31 March 2017	Feedback Meeting and Focus Group

3.1.1 Interview and Observe Subjects in Windhoek

To serve as a comparison for the informal recycling system in Oshakati and to understand the recycling capacity of Namibia in general, the team observed the Windhoek waste management and recycling system. On 22 March 2017, the City of Windhoek (CoW) Solid Waste Management Division (SWM) hosted a presentation and tour. First, a member of the Operations department of the CoW SWM presented a slideshow about the city's role in municipal waste management, followed by a question-and-answer session. To understand the process of sorting and baling recyclables for processing in South Africa, the team then took a tour of the Windhoek Rent-A-Drum (RAD) materials recovery facility (MRF). Since RAD may consider this project to be competition, the team did not discuss the project with the facility workers and instead requested a simple tour to observe the current process. During the tour, there were opportunities to ask questions, but this was not a structured interview. The questions investigated the source of RAD's materials, who collects the materials, and the types of processing they perform on the materials before shipment to South Africa. The following are some important questions from the tour:

1. Where do the materials that you process come from?
   This question intended to determine the structure of the Windhoek recycling system and the importance of waste collectors in the recycling process.

2. What quantities of recyclables do you collect each month, in weight, for each type of material?
   This question intended to understand the scale of recycling in Windhoek for comparison to the amount of materials collected in Oshakati.
3. What improvements to the local recycling system would benefit your company?
   This question gave RAD a chance to share their ideas for improving the Namibian recycling system.

After the tour of RAD, the team visited the Kupferberg Landfill, the only licensed landfill site in Namibia. The team held a semi-structured interview with the manager of the contracting company currently in control of the Kupferberg Landfill. The following are examples of questions asked to the Kupferberg Landfill contractor:

1. How much do private recycling collection companies pay for recyclables?
   This question intended to compare the prices of recyclables in Windhoek with those in Oshakati.
2. What changes have you seen in the waste management and recycling system since you have been working at the landfill, particularly in terms of payments or collection strategies?
   The team sought insight on improvements to the Windhoek recycling structure that could apply to Oshakati.
3. What should we keep in mind when designing a processing system?
   This question intended to obtain preliminary ideas on the design of a processing system for Oshakati.

Appendix A exhibits the informed consent statement shared with all interview subjects and Appendix B includes the full list of interview questions for the Kupferberg Landfill contractor.

3.1.2 Interview and Observe Oshana Region Informal Waste Collectors

This project aims to improve the quality of life for IWCs in Oshakati by increasing their generated income. In the current system in Oshakati, IWCs contribute to the recycling process by collecting and sorting recyclable materials from the local dumpsite and selling them to private recycling packaging companies. In the proposed system, IWCs collect, sort, and process the materials before selling them. The specific skills, needs, and suggestions of IWCs from Oshakati and two nearby towns influenced the final recommended recycling system design. To get a broader understanding of the local recycling system and a variety of thoughts and opinions, the team interviewed IWCs from Ongwediva and Ondangwa, as well as from Oshakati. Furthermore, IWCs from these neighboring towns may have a role in the Oshakati processing system in the future making it important to value their opinions during the interview process.

Ongwediva and Ondangwa Informal Waste Collectors

The team traveled to both the Ongwediva and Ondangwa dumpsites to interview the IWCs operating at these two locations. Although the project aims to ultimately contribute to Oshakati's recycling system, similar towns could either adapt or join a recommended system in the future. The team conducted a semi-structured interview with a group of five female IWCs at the Ongwediva dumpsite, and with a group of five female IWCs and two male IWC supervisors at the Ondangwa dumpsite. NUST student Stefanus Kalangula verbally translated the questions from English to the local language of Oshiwambo, and then translated the IWCs' responses back to English. The interviews inquired about current IWC practices and the IWCs' thoughts on introducing small-scale processing into their local system. The questions avoided sensitive subjects, such as income and education levels. After the Ongwediva interview, the team modified the list of questions slightly for clarity and ease of translation for the Ondangwa interview. Appendices C.1 and C.2 provide full lists of questions asked to both sets of IWCs. The following are some of the most important questions included in both interviews:

1. Which companies do you sell your recyclables to and which company do you prefer to sell your recyclables to?
   This question aims to understand the relationship between the IWCs and the recycling packaging companies. It also prompted the IWCs to provide the name of a company from which this study could collect data on the value of recyclables.
2. How are you compensated for the materials that you sell to this company?
   This question was important for comparing analyses of potential processing systems to the current situation.

3. What are your thoughts about working in a local recycling processing system?
   The team needed to ensure that the IWCs would be interested in the recommended processing techniques. This question also gave IWCs the opportunity to make suggestions and express concerns.

Before asking any questions, the team clearly described the research project and informed the interviewees of their right to remain anonymous and to leave the interview at any time. Appendix A provides this statement. Interview subjects gave full consent at the beginning of each interview for this project to include photos from the interviews.

Oshakati Informal Waste Collectors

The team, with the help of sponsor liaisons Clarence Ntesa and Lameck Mwewa and NUST students Stefanus Kalangula and Martha Haukena, organized and conducted a formal feedback meeting and focus group with the IWCs of Oshakati in a conference room at the Oshandira Lodge. Twenty-two IWCs attended this meeting and the lodge provided breakfast and lunch for each attendee. Martha Haukena was the primary meeting facilitator while Stefanus Kalangula verbally translated all IWC responses from Oshiwambo to English. The team recorded in writing all translated information. The feedback meeting consisted of the team's presentation and facilitating a discussion about the 2016 Recycle by Bicycle initiative, and the focus group included activities and a discussion regarding implementing a recycling processing system in Oshakati. The full meeting agenda was as follows:

1. Opening prayer by an attending IWC;
2. Opening remarks from the manager of Public Health and Environmental Management, an executive member of the OTC;
3. Introduction of WPI and NUST students and sponsors;
4. Introduction of each IWC including their name, number of years they have worked as an IWC, and if they were aware of the Recycle by Bicycle initiative;
5. Recycle by Bicycle progress and findings presentation by Martha Haukena;
6. Open discussion about IWCs' thoughts on the initiative;
7. Activity in which each IWC anonymously wrote down his or her monthly income on a slip of paper for the project's records;

8. Pin board activity in which each IWC voted on the top three most prevalent challenges in the dumpsite;
9. Open discussion on how these challenges could be eased and ideas for improving the local recycling system;
10. WPI recycling processing presentation in which the team showed the IWCs images of small-scale recycling processing techniques;
11. Open discussion about IWCs' thoughts and concerns on introducing processing machines to the dumpsite;
12. Closing remarks from Lameck Mwewa;
13. Ending prayer from an attending IWC.

The pin board activity (agenda item 8) provided the IWCs with an opportunity to express their concerns with the current collection system. In this activity, a pin board displayed the following six challenges IWCs face in the Oshakati dumpsite in their local language of Oshiwambo:

1. Nonnegotiable material selling prices;
2. Low earnings;
3. No weight scale in the dumpsite to ensure proper pay;
4. No equipment to assist in collecting or sorting;
5. Long hours working in the sun;
6. Lack of protective gear.

The team chose these six challenges based on background research and feedback from the Ongwediva and Ondangwa IWC interviews. The team gave each Oshakati IWC three stickers and asked them to place their stickers on the pin board to vote for the top three most prevalent challenges in the dumpsite. In addition to this activity open discussions encouraged IWCs to share their opinions and ideas regarding potential solutions to these challenges. Appendix C.3 contains a more detailed agenda for the feedback meeting and visuals used to explain potential processes to the IWCs.

3.1.3 Interview Recycling Packaging Companies

Another important group of stakeholders interviewed were independent recycling packaging companies in Northern Namibia. These companies collect recyclables directly from households and businesses as well as purchase materials from IWCs operating in the landfill. All recycling packaging companies in Oshakati bale and package the materials for transportation to end-stage processing facilities in South Africa. This investigation focused on Rent-A-Drum (RAD) and Wilco Recycling Company as the two companies to consider during this study, as they are the only two companies that buy materials from IWCs in the region. The team traveled to both RAD in Oshakati and Wilco in Ondangwa to tour the facilities and to conduct semi-structured interviews. The team spoke to Mr. David Henok, the local branch supervisor for RAD, and to Willem Coetzee, the owner of Wilco. These interviews inquired about the current operations of each company, and explored Mr. Henok's and Mr. Coetzee's thoughts on implementing recycling processing in Oshakati. These interviews also inquired about statistics on the abundance of each recyclable collected per month in the area and the prices at which they purchase and sell each material. To encourage participation in the interviews and to prevent RAD or Wilco from seeing the project as a threat to their current operations, the interviews focused on what each company might be able to contribute to the potential processing system. The following are some of the key questions from these interviews:

1. What quantities of recyclables do you collect each month and how much of this material is purchased from IWCs?
   This question gave data to understand the scale of recycling in the region and the rate at which IWCs collect materials.
2. Where do you send your baled materials?
   This question offered a better view of the entire recycling process and provided contacts for further processors that buy baled and partially processed recyclables.
3. What do you foresee as the role of your company in such a local recycling processing system in Oshakati?
   This question gauged company interest in participating in a local processing system.

Appendix D provides the list of interview questions asked to Mr. Henok and Mr. Coetzee.

3.1.4 Meet with the Oshakati Town Council

The Oshakati Town Council (OTC) oversees IWCs' work in the Oshakati dumpsite and determines the local waste management laws. Therefore, their views about recycling in Oshakati were important for this study to consider. The team presented processing ideas to eleven Oshakati town officials and held a discussion to gauge interest in developing a local processing system. The officials explained existing laws and made suggestions about the requirements and restrictions for a recycling processing system in Oshakati. The team also asked the officials for their ideas on improving the local recycling system, focusing on options for operational strategies and the potential for the OTC to invest in a processing system for IWCs. The discussion prompts presented to the OTC were as follows:

1. Would you support such a processing initiative?
   This question gauged the interest of the OTC.
2. How do you envision such a system to be managed and operated?
   This question prompted the OTC officials to share and discuss ideas for operational strategies.
3. Overall, what are some of the key considerations to ensure a successful system?
   This question opened the conversation to any considerations or concerns the OTC has about implementing processing in their town.

Appendix E provides the full presentation for the OTC, including the three discussion questions.

3.1.5 Contact Manufacturers/Potential Customers

To collect information on the types of processed recycled materials potential customers might be willing to purchase from a local processing system, the team contacted recycling processing companies as well as manufacturers in Namibia and South Africa. Through background research and information provided by recycling packaging companies during interviews, the team compiled the following lists of processing companies and manufacturers that may have an interest in purchasing locally processed materials:

1. Recycling Processors
    a. Consol Glass Company

       This South African company processes recycled glasses and uses it to manufacture glass packaging products.
    b. Collect-A-Can

       This South African company processes recycled cans and tins by cleaning and shredding the metal. They sell the shreds to manufacturing companies to turn into new products.
    c. Mpact Limited

       This South African company processes recycled plastics and uses them to manufacture plastic packaging products.
    d. Plastic Packaging Polymer Recyclers

       This Namibian company purchases recycled plastics and processes them into pellets, which they sell to plastics manufacturers.
2. Manufacturers
    a. Plastic Packaging

       This Namibian company with locations in Windhoek and Oshakati extrudes plastics to produce packaging products.
    b. Polyoak Packaging

       This Namibian company manufactures plastic packaging products.
    c. North West Plastic Manufacturers

       This Namibian company purchases recycled plastic pellets and uses them to create new plastic products.

The team contacted each company by phone and email. A series of questions sent to each company via email inquired about the materials these companies purchase, including their current suppliers, the types and forms of recycled materials they purchase, the volumes and quality of material they require, and the price they currently pay for their materials. The questions also inquired about what processes these companies use to recycle materials, and what products they sell to other companies. The team asked whether or not each company would be interested in purchasing processed recycled materials from a local, small-scale supplier. These questions aimed to identify potential customers to whom the IWCs could market their products, as well as provide data on the types of materials that would be most profitable and marketable to process in the Oshakati dumpsite. Appendix F.1 and F.2 present the project description and full lists of questions asked to each company by phone or email.

3.2 Objective 2: To Evaluate Potential Strategies for Adding Value to the Recyclable Materials

The team evaluated and coded the data collected in the stakeholder interviews to determine the most appropriate processing systems for the town of Oshakati. The coded interview data guided the process for identifying and evaluating potential strategies for adding value to the recyclable materials. The beginning of Chapter 3 defines a "recycling processing system" for the scope of this project as a combination of a process and operational strategies. This phase of the project included determining the most profitable material to process using data on availability and value of recyclables and identifying primary processing methods to consider from the stakeholder interview notes. This data narrowed down the list of potential recycling processes through stakeholder feedback and cost-benefit analyses (CBAs).

3.2.1 Organize and Analyze Data from Interviews

Following the interviews, the four team members combined interview notes into a complete set of question-and-answer notes for each interview. Two team members then began the coding process by identifying three major coding categories:

1. Current Challenges
   This category includes any comments regarding challenges the stakeholders experience with respect to the current recycling system in Oshakati. This coding theme identified the main concerns IWCs have about their current jobs that they want an improved recycling system to address.
2. Processes
   This theme consists of any suggestions, requests, or criteria for potential recycling processes and processing equipment. This category assisted in selecting the most appropriate process for the project stakeholders.

3. Operational Strategies

This category incorporates any comments and ideas regarding the integration of a recycling processing system into the community as well as organizational and operational structures. Identifying the suggestions and requests of the various stakeholder groups facilitated this project's recommendations for the most effective operational model for the processing system.

The team color-coded these categories by assigning each of the three themes a unique highlighter color. Then two team members read through the interview notes in search of any key words or statements that apply to one or more of these categories, highlighting each word or phrase with the appropriate color. Two team members each coded three interviews in this manner, then exchanged notes and reviewed the other's coding. Figure 19 is a sample of the highlighted document following this first level of coding. In this example, yellow represents current challenges, green represents processes, and blue represents operational strategies.

Current Challenges	Processes	Operational Strategies

INTERVIEW RESPONSES FROM RENT-A-DRUM OSHAKATI

Current Operations

1. *Can you please tell us about your company and the work that you are involved in?*
   RAD Oshakati collects as much recyclables as possible in Northern Namibia, sorts and bales the materials, then ships them to Windhoek. From Windhoek, the materials are combined with the materials baled there and shipped to South Africa for further processing.
   RAD Oshakati cannot ship directly to South Africa because they do not collect enough materials on their own to fill a truck to efficiently transport them.

2. *Have there been any attempts to improve the recycling system within your company?*
   RAD has stopped sending waste that got mixed in with recyclables to the landfill. Instead, they sell it to be used for energy.
   Want better training to teach collectors how to sort better so materials can be collected more efficiently.
   Mr. Henok sees Oshakati dumpsite collection as largest potential for growth. He would like to bring a baler to dumpsites so materials there can be collected more efficiently. His idea is to use a small baler that can be transported on a trailer to the dumpsite
   a) *Who initiated these changes?*
   Mr. Henok.
   b) *What has worked and what has not?*
   They have not been implemented yet.

Our Study

3. *What do you foresee as the role of your company if such a local recycling processing system was established in Oshakati?*
   Mr. Henok could not see further processing being implemented in Oshakati, but would like to implement a dumpsite baling system to make RAD's operations more time-efficient. He sees this as a huge potential for RAD and recycling in Oshakati; there is a lot of material in the dumpsite, but collection is inefficient because IWCs are neither officially employed nor properly trained.
   Mr. Henok would like RAD to purchase this baling machine, but nothing has been done yet.

Figure 19: Interview coding example

Once all of the interview notes underwent this initial phase of coding, the team divided them into three sets of data, one for each category. This method organized each category into a document containing only the information highlighted with its assigned color. Then, the team performed a secondary phase of coding for each of these documents. Together, the two team members identified four to six emergent sub-codes per primary category, assigned new highlighting colors, and coded the documents according to these new secondary themes. The following outline states the emergent sub-codes identified for each major category used for second level coding:

1. Current Challenges
   a. Lack of Collection/Processing Equipment
   b. Lack of Protective Safety Gear

    c. Long Hours
    d. Low Earnings/Unsatisfactory Prices
2. Processes
    a. Feasibility of Processing System
    b. Maintenance of Processing Equipment
    c. Material to Process
    d. Processing Equipment
3. Operational Strategies
    a. Governing Structure
    b. Investors/Funding
    c. IWC Organizational Structure
    d. Marketability
    e. Method of IWC Payment
    f. Training

Using the first and second levels of coding, the two team members analyzed the opinions of each stakeholder group with respect to each of the three primary coding categories. Using the "Current Challenges" and "Processes" coded documents, the team members listed the suggestions and requirements for recycling processes and equipment that each stakeholder articulated. This list identified stakeholder considerations for the recommended processing system. As with the primary coding themes, the team used a unique highlighter color for each of the secondary considerations. Two team members then coded the original complete interview notes again using these new themes.

The same method identified stakeholder considerations regarding operational strategies for the recommended recycling processing system. The team again assigned each major consideration a color and coded the complete interview notes according to these new codes.

Next, the team created two data tables, one for process considerations and one for operational strategy considerations. Table 7 provides the format for the two tables with the left column listing all of the interviewed stakeholder groups and the top row identifying the set of considerations. Checkboxes identify which stakeholder groups value each key consideration, as the coded interview notes suggested. This study deemed a consideration valued by a stakeholder group if the whole group agreed it was important. In this example, all six stakeholder groups believe considerations 1 and 2 are important to a successful processing system in Oshakati. Section 4.3.1 describes the full analysis of stakeholder considerations.

Table 7: Example table for recording stakeholder considerations

Stakeholder	Consideration 1	Consideration 2	Consideration 3	Consideration 4	Consideration 5	Consideration 6
Oshakati IWCs	✓	✓	✓	✓	✓	
Oshakati Town Council	✓	✓	✓			✓
Ongwediva IWCs	✓	✓	✓	✓	✓	
Ondangwa IWCs	✓	✓		✓	✓	
RAD	✓	✓				
Wilco	✓	✓				

To quantify the data recorded in the considerations table, the team assigned weights to each stakeholder group according to that group's importance to the project. Figure 20 depicts the weights assigned to each stakeholder group. Oshakati IWCs received the highest weight because they are the primary intended beneficiaries, and the goal of this project was to find the recycling processing option that best satisfies their needs while adding value to the material they collect. The OTC has the next highest influence because it has authority over the local dumpsite and its operations, and is a potential investor for a local processing system. The team assigned Ondangwa and Ongwediva IWCs identical weights, equal to half the weight of the OTC. Although they are not the focus of the project, the working conditions of these IWCs are similar to those of Oshakati IWCs, so their input is supplemental to the information provided by the Oshakati IWCs. Additionally, if the recommended system is successfully implemented in Oshakati, neighboring towns, such as Ondangwa and Ongwediva, could adapt a similar system to benefit their IWCs. Finally, RAD and Wilco have the lowest influence weights because the project does not aim to increase their roles in the local recycling system. However, these companies still received weights because they currently have significant involvement in the local recycling system.

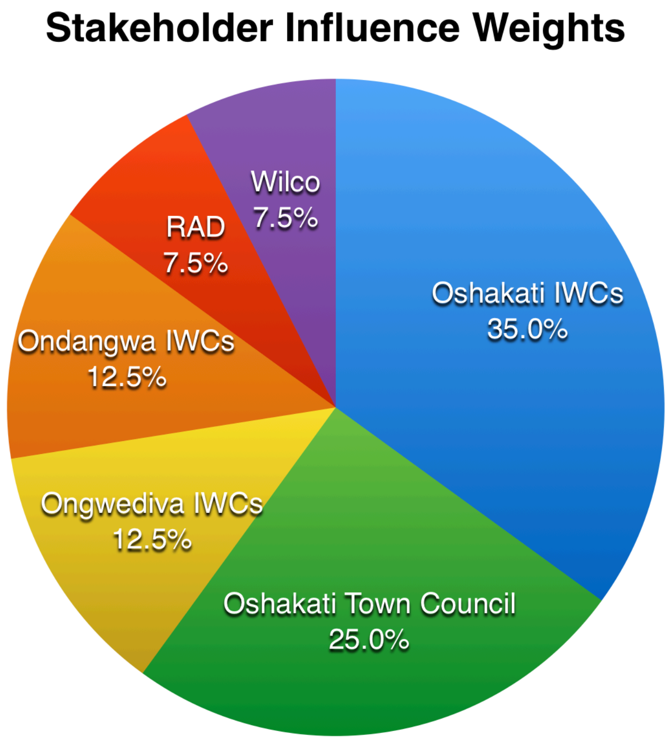


Figure 20: Stakeholder influence weight chart

The team applied these stakeholder influence weights to the data in the two considerations tables. Boolean values quantified each checkbox in Table 7. A checked box represents a value of "1" and an unchecked box represents a value of "0". These Boolean values, multiplied by the respective stakeholder influence weights, yield a weighted sum for each consideration. The values of these sums represent the overall importance of each consideration, with a value of "1" being the maximum possible importance. These weighted sums intended to suggest the most influential processing and business considerations to the success of the recommended system.

3.2.2 Determine Potential Processing Materials to Consider

The team considered both availability and value when identifying potential recyclable materials to process locally in Oshakati. This investigation used data from a 2013 study by Alsins et al. (introduced in section 2.3.2), given this is the most comprehensive and reliable study on waste quantities in Northern Namibia to date. This data, combined with information obtained from stakeholders on the sale values of different recyclable materials, yielded the potential profitability of each recyclable material type in the Oshakati dumpsite. These calculations assumed the following:

1. The waste quantities reported in the 2013 study by Alsins et al. are still accurate.
   This is the most recent and most comprehensive study on waste quantities in Northern Namibia.
2. The IWCs will be able to collect, process, and sell the full amount of the selected material(s) delivered to the Oshakati dumpsite each week.
   The recommended process intends to increase IWC earnings by adding value to the selected material(s). The IWCs should be able to focus on collecting the selected material(s) rather than all types of recyclables present in the Oshakati dumpsite. Assuming the IWCs are able to collect all of the available selected material(s) served as an upper bound when calculating potential earnings from processing.
3. The IWCs will be able to sell the processed material(s) for the same prices at which Wilco currently sells baled materials to South African processing companies.
   The prices that Wilco reported are the most accurate and complete set of values available to the team. These prices served as a reference for the potential revenue from processing the material. Processing material adds more value than simply baling, so the IWCs could potentially sell their processed materials for higher prices than the ones used in these calculations.
4. The number of IWCs working in the dumpsite will remain constant at 30 workers.
   There are currently 30 IWCs working in the Oshakati dumpsite. There are restrictions on who can work on the dumpsite so this number does not change frequently. The team used 30 workers as a constant to simplify the calculations.

The team used these calculations as well as background research regarding recyclable processing techniques to determine the most viable materials for IWCs to process in the dumpsite. This project focused on investigating these most viable materials for processing.

3.2.3 Determine Potential Processes to Consider

After identifying the most profitable materials to process, this study investigated potential recycling processes and processing equipment for the chosen materials. A recyclable can undergo different processes that each yields a distinct material form. For example, chips, shreds, and pellets are all processed forms of plastics, as Section 2.4.4 details. Each of these forms has different applications in industry. Through background research and information from communications with manufacturers and processing companies, the data revealed the material forms that would have the greatest appeal to industrial markets in the region. Investigating the most marketable material forms helped to identify the processing techniques with the highest potential to add value to the chosen materials. Additionally, the team eliminated complex processes that IWCs would not be able to effectively perform in a dumpsite setting. The team deemed a process complex if it requires the addition of external resources, such as water or chemicals, or if it involves multiple successive processing stages and significant manpower. After applying these constraints, the team was able to select multiple potential processing techniques to further investigate for the Oshakati dumpsite.

The investigation researched various equipment types and machines that perform these selected processes, focusing on small or medium-scale equipment that could be most effectively integrated into the Oshakati dumpsite. The study considered the following to determine the viability of different machines:

1. Output capacity

   The machine(s) should have the capacity to process the full quantity of the selected material(s) available in the Oshakati dumpsite. This enables the IWCs to maximize their potential profits from processing.
2. Energy consumption

   The machine(s) should consume energy at a minimal rate to reduce fuel and operating costs. The dumpsite does not have access to the Oshakati energy grid, therefore the machine(s) must be able to operate using off-grid energy sources.
3. Cost

   The machine(s) should have minimal initial and maintenance costs, while satisfying all other considerations.

This research investigated a variety of energy source options to provide a broad comparison between potential processes. The team researched designs for small-scale processing equipment that can be powered manually using hand-cranks or bicycle pedals. For electrical machinery, the project considered portable diesel generators and solar panels as potential energy sources. The study investigated these sources for their simplicity and availability in Namibia. Generator King and Solar Age Namibia are two Namibian companies that manufacture generators and solar panels, respectively. The study researched the product inventories of these companies to identify generators and solar panel models that meet the energy consumption requirements of each processing machine considered in this project.

Using the aforementioned considerations, the project narrowed down the list of potential processing equipment to investigate. For each of the chosen processing techniques, the next step was to select three equipment options to investigate: a small-scale machine powered manually, an industrial machine powered with a Generator King diesel generator, and an industrial machine powered by Solar Age Namibia solar panels. This step employed cost-benefit analysis (CBA) and other techniques, which this chapter later details, to determine the processes and processing equipment that would be the most effective at increasing earnings for IWCs.

3.2.4 Conduct a Cost-Benefit Analysis

This investigation included a CBA of each potential process established by the previous section. A CBA determines whether an endeavor is worthwhile by totaling and comparing benefits and costs. This analysis was a systematic approach to determine the strengths and weaknesses of each potential system and produced a cost-benefit ratio for each system as a unit for comparison. A cost-benefit ratio greater than one indicates that the benefits outweigh the costs of the process. This CBA examined the initial implementation of a potential system as well as its operation over the next ten years. The analysis examined both the initial and annual costs for machinery purchases, maintenance, and fuel, along with the benefits from annual revenue. The team researched and contacted various recycling machinery manufacturers to obtain price quotes, machine output capacities, and fuel consumption rates for each process considered. Additionally, this research involved contacting local suppliers of diesel, diesel-powered generators, and solar panels to acquire accurate estimates for fuel costs. To estimate maintenance costs, the study referenced a handbook published by Agricultural & Applied Economics Association. This publication, "Commodity Costs and Returns Estimation Handbook," investigated the change in maintenance and repair costs for various machine types as a function of operating time (Agricultural & Applied Economics Association, 2000). It provides a formula to calculate the accumulated maintenance cost, expressed as a percentage of the machinery sale list price, based on the accumulated number of operation hours for different types of machinery. Using this method yielded annual estimated maintenance costs for each potential machine.

To calculate the benefits of each process, the analyses included the output capacity of each machine, quantities of materials available in the Oshakati dumpsite, and the sale prices supplied by Wilco for baled materials. This assumes that the IWCs can collect all of the available materials in the dumpsite each week, and that the partially processed materials will sell at the same price as baled materials. It is likely that the IWCs can sell their processed materials at higher prices than baled materials, since the extra processing step adds value to the recyclables. Thus, this calculation of potential benefits is an underestimate, suggesting that the true benefits of each process are greater than those computed.

The team entered these cost and benefit values into a CBA spreadsheet for each potential process. For the initial year and subsequent 10 years, the spreadsheet calculates an annual cost, annual benefit, cost-to-benefit ratio, earnings per IWC per year, and earnings per IWC per month. The spreadsheet assumes that the number of IWCs operating in the Oshakati dumpsite will remain constant at 30 throughout the analysis period. The spreadsheet also computes the total costs and total benefits over the entire 11-year period, and uses these sums to calculate the overall cost-benefit ratio and monthly IWC earnings for each process. Appendix G contains the complete calculations spreadsheet used to conduct the CBAs.

3.3 Objective 3: To Prepare Recommendations for a Recycling Processing System in Oshakati

This study assessed the three systems with the highest cost-benefit ratios to determine the most profitable processes for the Oshakati IWCs. Then, the team applied the stakeholder processing considerations table to identify the most appropriate processing option that would increase income for IWCs and address all of the primary stakeholder concerns. The team used the stakeholder operational strategies considerations table and input from stakeholder interviews to develop an initial business model describing methods by which the IWCs could integrate the process into the dumpsite recycling system. The project's final recommendation to Oshakati discusses the top three processing options as well as operational strategies for a local recycling processing system.

3.3.1 Select the Final Processes to Recommend

The final step in the selection process utilized the CBAs to compare cost-benefit ratios and calculate monthly IWC earnings for the evaluated processes. These results revealed the three options that would yield the greatest increases in earnings for IWCs. Each of these options consisted of the selected material, processing technique, processing equipment, and energy source. The process then took into account the stakeholder considerations table (refer to Table 11 in Section 4.3.1) to evaluate the top three options and ensure they each satisfied the stakeholder considerations. The team selected the processing option that yielded the greatest cost-benefit results and met all of the stakeholder considerations as the most appropriate processing option to recommend to Oshakati. The project also incorporated recommendations for the processing systems that ranked second and third best in the CBA.

3.3.2 Develop Operational Strategies for the Recommended Processes

This project considered the following to develop an initial business model for implementing the chosen process into the Oshakati dumpsite:

1. Funding

   The team investigated methods by which IWCs can obtain processing equipment, such as government grants or private investments by sponsoring companies. In addition, the team evaluated strategies for IWCs or another investor to subsidize the initial investment and ongoing operating costs.
2. IWC organization

   The team investigated different organizational strategies for the IWCs. These included the number of IWCs that will operate the processing equipment and whether they will work in groups or individually.
3. Management

   The team evaluated management structures for the effective operation and regulation of the processing system. These included training programs, appointed supervisors, and a structured payment system for the IWCs.
4. Target markets

   The team investigated recycling companies and manufacturers in Namibia that may be interested in purchasing processed materials from the Oshakati IWCs. The team also *evaluated the possibility of IWCs continuing to collect other recyclables to sell to RAD and Wilco in addition to operating the processing system.*

To make recommendations for the aforementioned business model components, the project incorporated the suggestions the project stakeholders expressed through interviews and discussions. The analysis used coded interview notes as well as the operational strategies consideration table (refer to Table 17 in Section 4.5.1) to determine the most appropriate business model to effectively integrate the recommended processing system into Oshakati's recycling system.

3.4 Summary

This project's mission is to increase the earnings of IWCs in Oshakati by adding value to their collected materials. To accomplish this goal, the team first conducted interviews with key stakeholders in Oshakati and neighboring communities to develop a better understanding of the current waste management system. These interviews aimed to establish guidelines and provide suggestions for possible recycling systems. The project used the collected data to identify various options for processing systems. Each system included the material to process, the processing technique, the processing equipment, and an energy source for the equipment. The team conducted a comprehensive CBA to compare the effectiveness of the systems at increasing IWC earnings. The study identified the most profitable systems from the cost-benefit results, and used the suggestions that stakeholders expressed during interviews to develop an initial business model for the integration of a processing system into the Oshakati dumpsite. From this, the project provided final recommendations for a recycling processing system that would add value to the materials IWCs collect in the Oshakati dumpsite.

CHAPTER 4: RESULTS AND ANALYSIS

This chapter presents the findings from the stakeholder meetings and interviews in Oshakati and analyzes potential processing systems that could be implemented in Oshakati. The first section gives a brief summary of each stakeholder interview or meeting and the following section provides the analysis of materials and processes based on stakeholder information and opinions. The chapter closes with the results from the team's cost-benefit analysis and potential operational strategies.

4.1 Stakeholder Interview and Meeting Findings

This section presents the findings from the interview at the Kupferberg Landfill in Windhoek as well as the findings from interviews and meetings with the six stakeholder groups in the Oshana region. This investigation heavily considered these interview findings when recommending a recycling processing system for Oshakati.

4.1.1 Kupferberg Landfill Contractor Interview Findings

The team first interviewed the contractor at the Kupferberg Landfill in Windhoek. Part of his job consists of managing the waste that enters the landfill and paying collectors to pick and sort recyclables that he then sells to RAD. The interview focused on his relationship with the recyclable collectors, as these employees are similar to the IWCs found in Northern Namibia. There are 18 female and 4 male collectors in the landfill who work six days per week, eight to nine hours per day. The contractor pays these collectors the Namibian minimum wage for construction-related laborers of N$16.04 per hour.

In the morning collectors extract as many recyclable materials as possible from the arriving waste. In the afternoon, the workers sort the recyclables into designated bags or bins. RAD trucks go to the landfill to pick up the material and bring it back to the RAD facility for baling. One experienced collector is in charge of dividing the other collectors into small groups and assigning each group a particular material to collect and sort. The contractor stated that he trusts the collectors to do their jobs and does not supervise them closely, although there are surveillance cameras throughout the landfill if any issues were to arise. He assured the project team that he supplies the collectors with protective masks and gloves and that they undergo yearly medical inspections.

The landfill produces about 7,000 tons of waste each month, from which the landfill employees collected 181 tons of recyclables in February 2017. When RAD collects the recyclables from the landfill, the contractor weighs the RAD trucks before they leave the landfill, then RAD weighs them again upon arrival at the RAD facility. RAD pays the contractor for these materials based on weight and type of material. Table 8 shows the RAD price list for landfill recyclables per ton. These prices are from RAD Windhoek's pricing pamphlet that RAD provided the contractor.

Table 8: Windhoek RAD prices paid per material per kilogram

Material	Price per Kilogram (N$)
Cans, Aluminum	2.5
Cans, Other	0.45
Carton (K4)	0.18
Glass Mix	0.12
Paper - Flatnews	0.10
Paper- Supermix	0.30
Plastic, HDPE Bottles	0.42
Plastic, HDPE/PET Clear	0.42
Plastic, LDPE Clear	0.42
Plastic, LDPE Mix	0.27
Plastic, PET Bottles Mix	0.39

Kupferberg's contractor is not satisfied with the prices RAD pays for the landfill recyclables, and is currently losing money by selling these recyclables and paying the collectors minimum wage. He is looking at other options to increase the value of the materials his employees collect. The contractor believes that there is potential to process materials at the landfill and sell them to companies other than RAD. He has considered crushing glass and selling to private glass recyclers who have given him a quote of N$800 per ton. He has also considered selling metals to a South African metal recycling company called Collect-A-Can.

Collect-A-Can will provide the contractor with a free baling machine if he can supply 10 tons of steel and aluminum per month.

The contractor was not confident that there are sufficient materials available for local processing to be profitable in Windhoek. He worried that the capital investment for a large-scale processing operation would be too high for the material supply. He also stated that a new processing facility would compete with RAD for materials and would require a suitable market for selling the processed materials.

Overall, the team learned that the Windhoek waste system is very different than those in northern towns, such as Oshakati. Unlike in the northern towns, the CoW SWM requires landfill contractors to employ collectors to sort as many recyclables as possible. Since the Kupferberg landfill contractor formally employs collectors, these workers earn minimum wage. This landfill contractor system provides more regulation and efficiency to the recycling system in Windhoek, as compared to the informal system in northern towns. Appendix H contains the full notes from the Kupferberg Landfill contractor interview.

4.1.2 Informal Waste Collector Interviews and Focus Group Findings

Ongwediva Informal Waste Collectors Interview

The team spoke with the Environmental Health Officer for the town of Ongwediva. He described current conditions and management policies that the town has set in place at the dumpsite. The town restricts access to the dumpsite and requires all IWCs operating there to register with the town. The town also provides protective equipment such as gloves and long sleeve shirts for the IWCs.

Upon arrival at the dumpsite the team interviewed a group of five women who currently work as registered IWCs. Town officials and supervisors were not present for this interview to avoid biasing the interviewee responses. These women have been working in the dumpsite for two to seven years. The typical workday begins at 06h00 and ends at 19h00 from Monday to Friday and Saturday on occasion. Each collector gathers recyclable material throughout the day and sorts it by type at the end of the day. No system is currently in place for measuring the volume of recyclables that the IWCs collect. The IWCs rely on recycling packaging companies to weigh and price their collected materials for payment. The only processing that the IWCs perform is breaking glass bottles by hand.

The town only allows Wilco to collect recyclables from the Ongwediva dumpsite. Wilco sets prices that they pay per kilogram of recyclables collected. The IWCs stated that representatives from Wilco arrive at the end of each month to collect all recyclables. The representatives take the materials back to Wilco for weighing and packaging. The representatives return on a later day to pay the IWCs for the collected materials. The IWCs are concerned that there is a long delay between material collection and payment, and they also believe they are consistently being underpaid. They became frustrated when discussing the topic of payments, suggesting it is a strong concern of theirs.

IWCs discussed their desire to bale and weigh the recyclables themselves. In the past they convinced Wilco representatives to bring a scale to the dumpsite so they can see the weight of their collected materials. The IWCs were skeptical about the accuracy of the scale and were not convinced that requiring Wilco to weigh the materials at the dumpsite would be effective in ensuring fair pay. The IWCs in Ongwediva stated that the change they would most like to see in the dumpsite is a method to ensure that they are paid a fair price, and they welcome any initiative that will increase their income.

When discussing recycling processing, the IWCs showed a strong interest. They did not know the processes that the materials undergo after leaving the dumpsite but once the team explained the processes, they were interested in processing their own materials. All five IWCs present expressed interest in using processing machinery if they received training. Their main concern is the marketability of processed materials in the area. They would like to sell to companies other than Wilco but fear there is not a better option. Appendix I contains the complete interview notes from the Ongwediva group interview.

Ondangwa Informal Waste Collectors Interview

The Ondangwa Dumpsite has a different structure than the other two dumpsites in the area. There have been IWCs working in this dumpsite for three years and all seven of the IWCs interviewed have been working there for the full three years. RAD is the only recycling packaging company that purchases materials from the Ondangwa dumpsite. RAD employs two managers at the dumpsite who have organized the 12 Ondangwa IWCs into two groups. One group has five IWCs while the other group has seven. The IWCs split the dumpsite into two sides and only collect recyclables from their group’s assigned side. Each collector works to collect all types of recyclable materials from their side, then carries these materials to their group's designated area where they sort them into piles by material type. One male IWC from each group is called the "supervisor" and is responsible for communicating with the RAD managers.

The typical work hours for IWCs at this dumpsite are Monday through Friday from 08h00 to 17h00 and Saturdays from 08h00 to 12h00. Once a group determines that they have collected enough recyclables to sell, they call their manager who arranges a RAD truck to come collect the materials. RAD transports the collected materials to the Oshakati facility for weighing and baling. One or two days later RAD pays the dumpsite supervisor for the group's materials, and it is the supervisor's responsibility to divide the payment between the IWCs in his group. Sometimes all the IWCs receive equal pay, other times the pay is unequally divided according to "work effort" at the discretion of the supervisor. This collection and payment process typically occurs four or five times per month for each group.

The primary concern the IWCs expressed was that the payment process is not fair. They do not receive a record for the weight of the materials they collect. The supervisor does not know how much material each IWC collected so any uneven payments are subject to his judgment. The second main concern was safety. They stated that at the end of a workday they are often coughing due to inhaling smoke and other pollutants. Neither RAD nor the town provides them with any safety equipment.

When discussing the idea of processing materials at the dumpsite, the IWCs were very interested as long as they receive adequate training and all necessary protective equipment. An additional idea they suggested is working in groups. One group would focus on collecting as many materials as they can while the other group sorts and processes the materials. They believe this would be the most efficient way to structure the dumpsite to include processing and emphasized that they would split the profits evenly. Appendix J contains the complete interview notes from the Ondangwa IWCs group interview.

Oshakati Informal Waste Collectors Focus Group

Oshakati IWCs joined the project team for a focus group at the Oshandira Lodge in Oshakati. Twenty-two out of the 30 Oshakati dumpsite IWCs attended the event to share their thoughts about recycling processing. IWCs have been working in the Oshakati dumpsite for the past 20 years. Some of the IWCs currently working at the dumpsite have been there the entire 20 years while others have been working in the dumpsite as little as two years.

The main purchaser from this dumpsite is Wilco. Wilco collects materials two or three times per month and weigh them back at the Wilco recycling yard. The owner of Wilco returns to pay each IWC based on the amount of materials they collect. RAD collects recyclables from the Oshakati dumpsite once or twice per year if they are very low on a particular material and need an additional supply to meet their monthly quota.

IWCs work from 08h00 to 17h00 and can choose to work either five or six days per week. Each IWC collects, sorts, and sells all types of recyclables individually. Hence, when the team requested that each IWC report his or her monthly income, there was a large range of salaries. Responses varied from N$300 to N$950 with an outlier who reported a salary of N$1,500. This is a sensitive subject, which could account for any biased responses including this outlier. The average salary was N$528, excluding the outlier. Figure 21 shows the reported salaries from the Oshakati IWCs, excluding the outlier. The IWCs do not support the Recycle by Bicycle Project because they believe that it wastes time. After Ms. Haukena presented the findings from the Oshakati pilot test, IWCs stated that they generate more money by collecting at the dumpsite than they would on the bicycle.

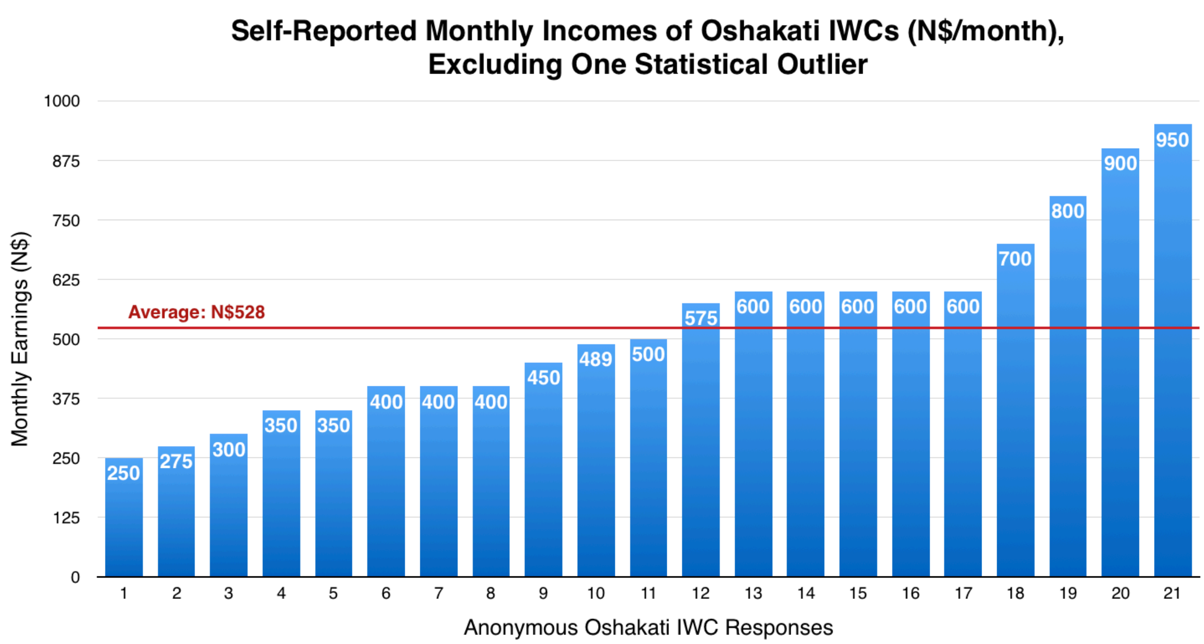


Figure 21: Self-reported monthly incomes of Oshakati IWCs ($N/month), excluding one statistical outlier

The pin board activity in which the IWC voted for the three most prevalent current challenges yielded the following results in Figure 22. Table 9 translates the pin board notecards from Oshiwambo to English. Note that the sticker colors are insignificant; each sticker on the pin board represents a single vote, regardless of color. This activity indicated the importantance of each issue to the IWCs. Their most prominent challenge is low earnings, while their second most prominent challenge is the lack of collection and processing equipment available at the dumpsite. These challenges aligned with the team's mission to increase IWCs earnings by implementing processing equipment. The IWCs discussed the idea of baling and weighing materials themselves and were excited about the idea of learning how to use machines.

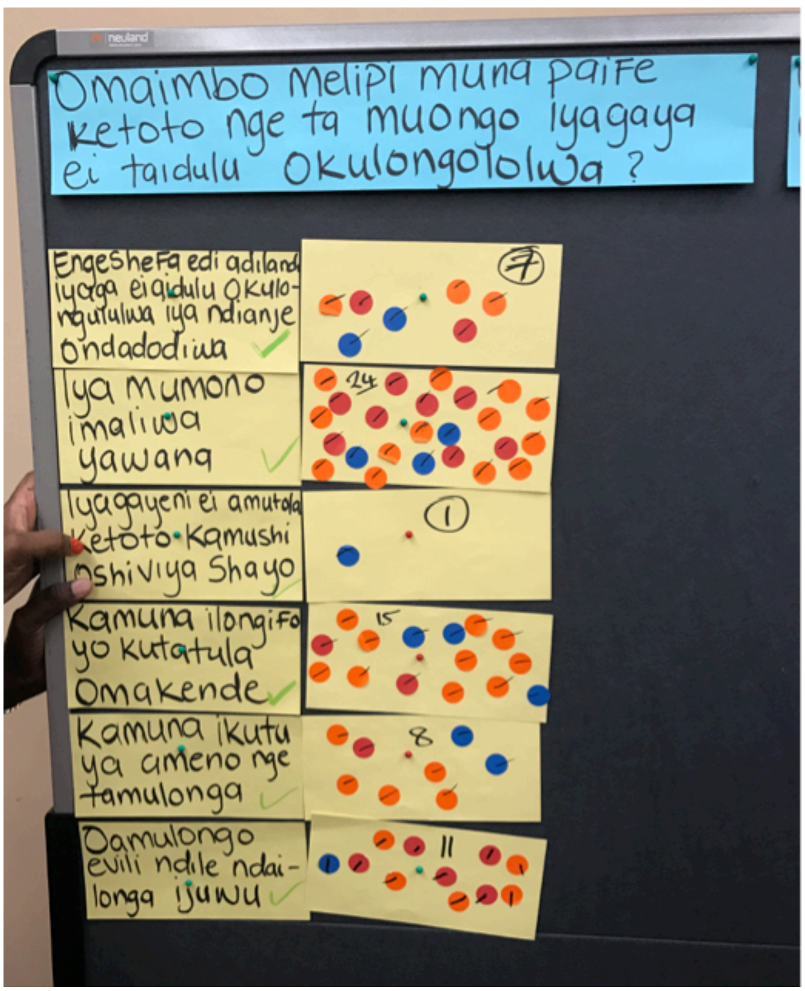


Figure 22: Results from prominent challenges pin board activity (n = 22, 3 votes per IWC)

Table 9: Translated results from prominent challenges pin board activity (n = 22, 3 votes per IWC)

Challenges	Number of Sticker Votes
The selling prices never change	7
Pay is too low	24
No proof of weight using scale	1
Cannot bale or weigh materials	15
Not enough protective equipment	8
Long hours in the sun	11

The team presented ideas about further processing strategies and the IWCs were visibly excited. They did not have a preference regarding processing types as long as the recommended process is more profitable than the current system. The team then asked questions regarding their ideal business model for this system. The IWCs said they would like to own any processing machines as a group. They believe they have the funds to invest in processing machinery, although they would like the OTC to monitor the investment to ensure fair quality and prices.

The IWCs also developed two possible options for everyday operations at the dumpsite if someone implements a processing system in Oshakati. One option would have one or two people trained to operate the processing equipment. The other IWCs would continue focusing on collection and give their materials to the operators for processing. In return each collector would give a percentage of their pay to the operators. The second option discussed was to split the IWCs into groups. Each day of the week one group would have the opportunity to use the machines to process all of their materials. This would require technical training for all IWCs, whereas the first option would require training for only one or two people.

By the end of the meeting, the IWCs stated that they are interested in anything that could help increase their income. They are interested in baling and weighing materials at the dumpsite and are willing to learn further processing methods in order to facilitate a local processing system. Appendix K contains the complete notes from the Oshakati IWCs focus group including the self-reported monthly earnings.

4.1.3 Private Packaging Companies Interview Findings

Rent-A-Drum Oshakati Interview

The team interviewed David Henok, the branch manager at the RAD Oshakati facility. RAD Oshakati collects as many recyclables as possible from households, businesses, and dumpsites in Northern Namibia, then sorts and bales the materials. RAD Oshakati collects recyclables from businesses and households in Ongwediva, Ondangwa, Okahao, and Oshakati, in addition to the Ondangwa and Oshakati dumpsites. Mr. Henok sends RAD employees out early in the morning to collect unsorted materials from town waste bins and businesses. RAD employees sort these materials at their Oshakati facility. Mr. Henok then sends employees to the Ondangwa and Oshakati dumpsites to buy additional recyclables collected and sorted by IWCs. After baling, RAD Oshakati ships the materials to Windhoek by truck. The RAD Windhoek branch combines the Oshakati baled materials with their baled materials before shipping them to South Africa for further processing. RAD Oshakati alone does not produce enough materials to efficiently transport them to South Africa without combining with RAD Windhoek materials.

Mr. Henok stated that IWCs are not officially employed by RAD; therefore they do not have a close relationship. Mr. Henok pays the IWCs once per month, and he determines their pay based on the weight of the material each IWC collects. He stated that it is challenging to track each IWC's individual collection and pay. Mr. Henok employs two supervisors at the Ondangwa dumpsite to oversee IWCs' collection and payment. The team asked during the interview for a list of prices RAD pays the IWCs for each material and Mr. Henok provided the list via email later that day. Table 10 in Section 4.2.2 displays these prices.

Mr. Henok would like to expand the RAD Oshakati branch and increase recyclable collection as much as possible in the region. He stated that the dumpsite contains large quantities of valuable recyclables, but IWCs are not able to recover it all because they do not receive proper training. Mr. Henok emphasized the need to provide training for IWCs on how to properly sort so materials can be collected and baled more efficiently. He could not see further processing of recyclables being successful in Oshakati, but he would like to implement a dumpsite baling system to make RAD's operations more time-efficient. His idea is to use a small baler on a trailer in the dumpsite so that IWCs can bale the materials as they collect them. Mr. Henok sees improved IWC training and a dumpsite baling system as having huge economic potential for

RAD and recycling in Oshakati. Appendix L contains the full interview notes and complete price list from the interview and follow-up emails with David Henok of RAD Oshakati.

Wilco Recycling Interview

The team interviewed Willem Coetzee, the owner of Wilco Recycling Company in Ondangwa. Wilco collects recyclables from households, businesses, and dumpsites mainly in Ondangwa, Oshakati, Ongwediva, and Oshikango. They sort and bale the recyclable materials before shipping them directly to South Africa for further processing. Mr. Coetzee stated that the Oshakati dumpsite is Wilco's main source of recyclables.

Mr. Coetzee employs 20 workers to bale and sort materials in the Wilco facility. He does not station supervisors or representatives at the dumpsites; instead Mr. Coetzee personally collects materials from IWCs and pays them based on the weight of the materials they provide. Mr. Coetzee also reported that he collects materials twice per week from the dumpsites in Oshakati and Ongwediva, contrary to the statements of the Ongwediva IWCs that he only collects materials once per month. The team asked during the interview for the list of prices Mr. Coetzee pays IWCs for each material and Mr. Coetzee provided the data via email later that week. Table 10 of Section 4.2.2 displays these prices.

Wilco owns a large, generator-powered baler as well as a small portable baler on a trailer. Wilco's operations usually produce about one truckload, or 80 bales, of recyclables per week. To save money on transporting the bales to South Africa, he uses a truck sharing system. He and another business share the cost to hire a truck that will drive Wilco's materials to Cape Town and pick up the other business's cargo for the return trip to Oshana. Each shipment to South Africa costs Wilco approximately N$19,000, making this cost the largest expense Mr. Coetzee would like to reduce.

Mr. Coetzee is in support of the idea of IWCs processing recyclables locally, and would be willing to purchase processed materials from IWCs. Appendix M provides the full interview notes and complete price list from the interview and follow-up emails with Willem Coetzee.

4.1.4 Oshakati Town Council Discussion Findings

The team met with 12 members of the Oshakati Town Council (OTC) to give an update on the NUST Recycle by Bicycle initiative and to learn about their interest in implementing a recycling processing system in Oshakati. The OTC's response to the team's project was very positive. They believe that the project goal is an attractive initiative to "turn waste into money," keep the Oshakati community clean, and create local jobs. They emphasized that the initiative should be community-based, with citizens volunteering and organizing themselves independently, although the OTC would be willing to help "create a platform" for the project. The OTC also suggested having each informal settlement elect a group of residents to be in charge of recycling collections. This would foster more jobs in these informal regions of the town. The OTC's main concerns were the economic sustainability of the processing equipment, where the machinery would be stored and maintained, and the willingness of the IWCs to participate in such an initiative. Some solutions the OTC, the project team, and the project sponsors discussed to address these concerns included selecting easy-to-use mechanical or solar-powered machinery, and ensuring that there is a local mechanic who will be able to repair and maintain the machinery. Appendix N presents the full discussion notes from the meeting with the Oshakati Town Council.

4.1.5 Manufacturers/Potential Customers Findings

Recycling Processors

The team contacted Consol Glass Company, Collect-A-Can, Mpact Limited, and Plastic Packaging Polymer Recyclers via phone and obtained an email address for a representative to assist us at each company. None of these companies responded to the inquiry emails or follow-up emails the team sent. The Consol Glass Company representative told the team over the phone that he was unable to receive permission from his supervisors in the company to release pricing data and other information the email requested, due to fear of competitors obtaining this information. The only detail he provided was that Consol Glass Company only purchases mixed crushed glass, called collet, from unnamed suppliers in South Africa and Namibia. They do not require glass to be sorted by type or color. After multiple phone calls and emails, no other manufacturing company provided any response.

Manufacturers

The team phoned Plastic Packaging, Polyoak Packaging, and North West Plastic Manufacturers. Plastic Packaging requested that the team send the questions via email, but did not respond to this email nor subsequent contact attempts. A representative from Polyoak

Packaging stated over the phone that his company does not purchase any recycled materials and that they manufacture their products using virgin plastics only. He explained that RAD collects plastic scraps from Polyoak Packaging to recycle. The representative did not answer any of the other questions about purchasing recycled material, as they were not applicable to this company.

North West Plastic Manufacturers answered the team's questions via phone. The representative explained that his company manufactures HDPE pipe from a mix of recycled HDPE and LDPE plastic. North West Plastic Manufacturers purchases between 33 and 36 tons of recycled plastic pellets per month from unnamed suppliers in South Africa for N$11 per kilogram. He emphasized that the quality of the recycled pellets is the most important factor when the company chooses a supplier. They test the plastic they purchase in a laboratory to ensure that it meets specific quality standards, including mechanical strength and durability. He said his company might be interested in using material recycled by IWCs in Oshakati, as long as it is clean and meets their quality standards. He explained that they do not purchase shredded plastic, they only manufacture using fully processed pellets. He referred the team to Plastic Packaging Polymer Recyclers for questions regarding plastic recycling processing. Appendix O provides the full notes from the phone conversation with the North West Plastic Manufacturers representative.

4.2 Material Analysis

The first step to recommending a recycling processing system for Oshakati is to indicate which materials are the most abundant and most profitable in the region. This section takes into consideration the figures obtained from past studies on Oshakati's waste management system as well as the team's data obtained from stakeholders in the region. This material analysis eliminates unprofitable materials from the team's considerations and recommends four materials to further consider in the process analysis section.

4.2.1 Material Availability

From observations and interviews with IWCs and private recycling packaging companies, the team identified the types of materials IWCs collect and sell. Background research revealed the materials that are most abundant in the Oshakati dumpsite. These observations aligned with the data reported in the 2013 Alsins et al. study titled “Analysis of qualities and quantities of waste and recyclables in the Namibian Towns”, suggesting that this is still an accurate representation of the materials available in the Oshakati dumpsite. Alsins et al. (2013) reported cardboard, plastics, paper, glass, and metals as the five most abundant material categories in the dumpsite (refer to Figure 11 in Chapter 2). Out of these five categories, the team chose to investigate plastics, glasses, and metals as possible materials for IWCs to process. Observations in the dumpsites indicated that paper and cardboard are difficult to collect as they disintegrate when exposed to moisture, and are often low in quality due to rain and other contaminants. Additionally, background research suggested that the recycling techniques available to process paper and cardboard are complex and cannot be divided into stages, which would make them difficult to implement in the Oshakati dumpsite. For these reasons, the team decided to eliminate paper and cardboard from the study.

Plastics and metals can be subdivided into more specific material types. Figure 23 displays the most abundant plastic, glass, and metal materials in the Oshakati dumpsite, and indicates the quantities in kilograms of each material deposited at the dumpsite weekly. The 2013 study found that LDPE plastic bags and glass containers are very abundant in the Oshakati dumpsite, comprising 8.1% and 5.7% of the total waste respectively.

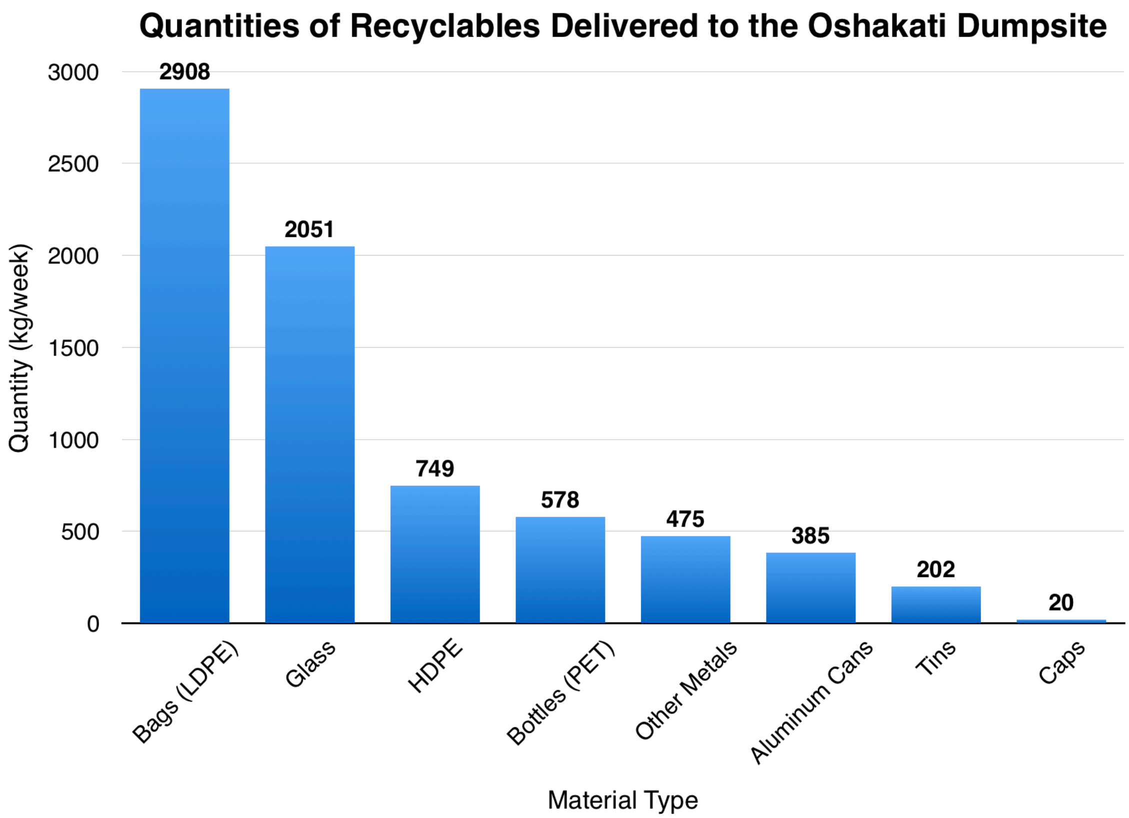


Figure 23: Quantities of recyclables delivered to the Oshakati dumpsite weekly in 2013 (adapted from Alsins et al., 2013)

4.2.2 Material Values

Both RAD and Wilco provided a full list of the prices they pay IWCs per kilogram of each type of material. Additionally, Wilco listed the prices at which they sell their bales of each material type to end-stage recycling processors in South Africa. Appendices L and M include the full lists provided by RAD and Wilco respectively, and Table 10 combines these lists for price comparison. For all materials except for glass, there is more than a 150% increase from Wilco's initial purchase price to the resale price. This demonstrates the effectiveness of baling and simple processing at increasing the value of recyclable materials.

Table 10: Oshana region material sale prices in Namibian dollars per kilogram

Material	IWC Sale Price to RAD	IWC Sale Price to Wilco	Wilco Sale Price to South Africa
Aluminum Cans	N$2.50	N$5.00	N$13.00
Bags (LDPE)	N$0.27	N$0.80	N$2.20
Bottles (PET)	N$0.35	N$0.80	N$3.50
Caps	N$0.37	N$0.80	N$3.00
Glass	N$0.12	N$1.70	N$0.92
HDPE	N$0.39	N$0.80	N$3.00
Other Metals	N$0.15	N$0.30	N$1.00
Tins	N$0.15	N$0.30	N$1.00

According to these prices, RAD offers lower prices per kilogram than Wilco for every type of plastic, glass, and metal. The IWCs confirmed in the interviews that Wilco pays higher prices for all materials. Additionally, the meetings with IWCs in Oshakati revealed that they sell more recyclables to Wilco than to RAD. Therefore, the team chose to use only Wilco's purchase prices when analyzing potential profitability of materials.

4.2.3 Material Profitability

The team examined the potential profitability of each viable material by combining Wilco's prices per kilogram with quantities of each material delivered to the Oshakati dumpsite each week in 2013. Figure 24 shows the total potential weekly revenue of IWCs and Wilco for each type of material. This calculation assumes that IWCs could collect, sort, and sell the full amount of these materials entering the Oshakati dumpsite every week. This suggests that LDPE bags and aluminum cans have the potential to generate large revenues based on both abundance and value.

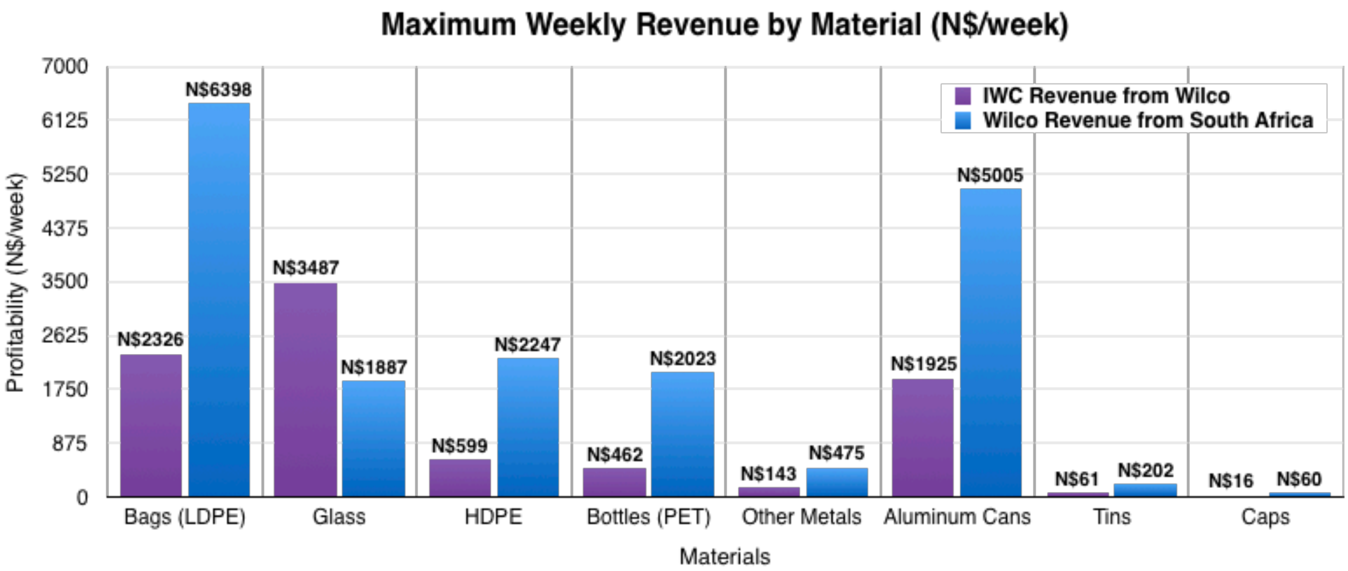


Figure 24: Maximum weekly revenue of IWCs and Wilco

Since the focus of the project is to increase the value of the materials IWCs sell, the team evaluated which materials have the potential to undergo the largest increase in value during processing. The difference between Wilco's resale revenue and the IWC's revenue from selling to Wilco approximates the value Wilco adds to each material through baling. Figure 25 shows this difference in maximum weekly revenue for plastic, glass, and metal materials, in order from greatest to smallest value increase. This calculation does not factor in the cost of the baling process or transportation to South Africa, so it is not a true representation of Wilco's actual profits. It illustrates the increase in material sale value from raw material form to baled form, assuming the IWCs collect and process the full available quantity of each material each week.

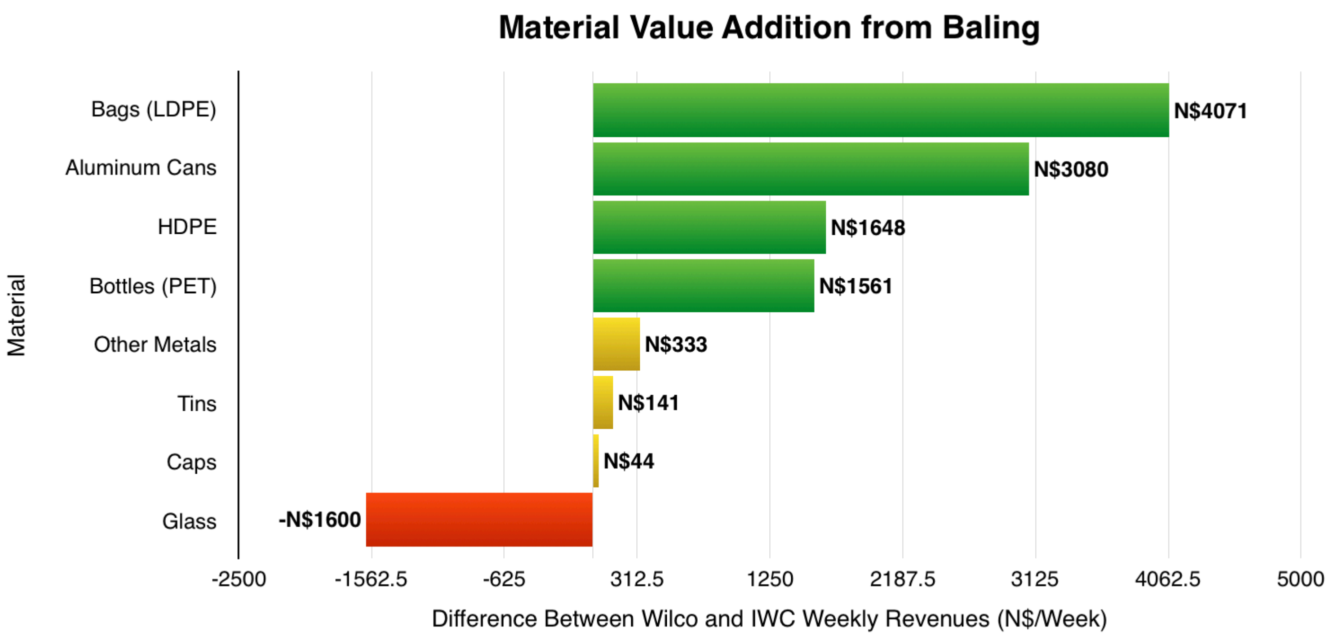


Figure 25: Wilco's weekly material value addition from baling

Figure 25 suggests that processing LDPE and aluminum cans have the most potential to increase IWC earnings, followed by HDPE plastics and PET bottles. Additionally, it indicates that the value of caps, tins, and non-aluminum metals cannot be significantly increased through baling, and are not worth investigating further in this study. Although this analysis only considered the process of baling and did not evaluate the value added to materials through other processes, it does factor in the prices further processing companies pay Wilco for the baled materials. The cost these further processing companies are willing to expend on baled material is positively correlated to the price they earn for their processed materials when selling to production companies. Therefore, an analysis of the value addition from baling is an indicator of the value addition from processing various materials. As shown in Figure 25, baling LDPE, aluminum, HDPE, and PET adds significant value to the raw material. Therefore, further processing of these four materials will also add as much, if not more, value than baling. For example, Wilco reported selling baled plastics for N$2.20 to N$3.50 per kilogram, depending on the type of plastic. North West Plastics Manufacturers stated that they purchased fully processed HDPE and LDPE pellets for N$11.00 per kilogram. This demonstrates the significant value addition that recycling processes add to materials. The team was unable to obtain a full list of further processing prices from processing companies, therefore these baled material numbers represent a lower-bound potential value that could be added to any processed materials. From this analysis, the team decided to investigate recycling processes for LDPE bags, aluminum cans, HDPE plastics, and PET bottles since these materials are the most profitable.

4.3 Processes Analysis

To determine the most effective recycling process system for Oshakati IWCs the team coded interview data and used it to help determine the processing options that will be most effective. In Section 4.2 the team decided (based on Wilco prices) that plastics and aluminum are the most profitable materials to bale and therefore the most profitable to process. After these materials are baled and sent to South Africa, the initial recycling processing step for both materials is shredding. The team examined both manual and industrial shredding machines to add value to the IWCs' plastics and aluminum.

4.3.1 Stakeholder Considerations

The team determined the most important considerations that need to be addressed when developing the recycling process for IWCs by coding interview transcripts as discussed in Chapter 3. The results of the coding are shown in Table 11. A checkmark in a cell represents that the row's stakeholder showed interest in the column's consideration during their interview. For example, the Oshakati Town Council showed interest in the maintenance of the recommended processing machine.

Table 11: Stakeholder coded process considerations

	Processing by IWCs	Increased Material Value	Marketability	Safety	Weighing	Maintenance
Oshakati IWCs	✓	✓	✓	✓	✓	
Ongwediva IWCs	✓	✓	✓	✓	✓	
Ondangwa IWCs	✓	✓		✓	✓	
Oshakati Town Council	✓	✓	✓			✓
RAD	✓	✓				
Wilco	✓	✓				

To quantify the data recorded in Table 11, the team assigned the value "1" to each checkmark, as Section 3.2.1 describes. Figure 26 displays the sums of the respective stakeholder percentage weights for each consideration. A total weighted importance of “1” indicates that all stakeholders determined that consideration to be important.

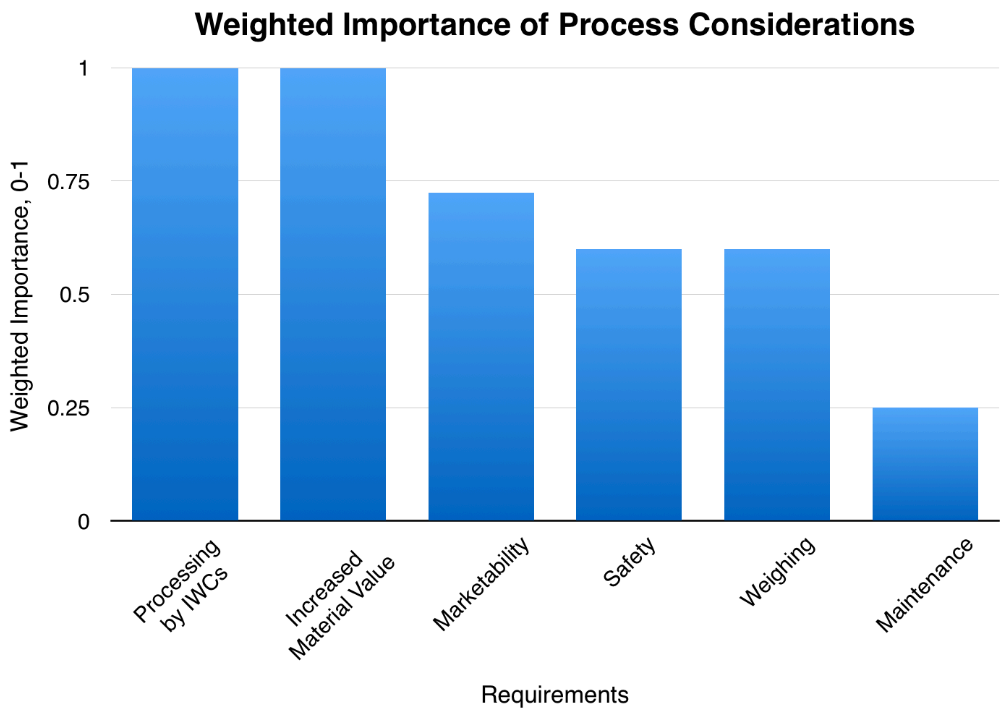


Figure 26: Weighted importantance of process considerations

Figure 26 shows the most important process considerations are processing recyclables by IWCs and increasing the value of recyclables.

4.3.2 Manual Processing

Manual equipment can process plastics including LDPE, PET, and HDPE. Figure 27 shows an example of such a device, “The Ingenio” bicycle-powered shredder designed by Victor Monserrate (Holaciudad, 2013). The operator of this device pedals the bike, which turns the bicycle gear and rotates the shredder blades. Another operator cuts the plastic into small pieces and feeds them into the shredder as the gears turn to produce the final shredded plastic product. A safety cover around the shredder blades would ensure worker safety when the machine is not in use.

Figure 27: "The Ingenio" bicycle-powered plastic shredder (Holaciudad, 2013)

An advantage to this processing method is the low initial costs compared to a larger-scale electric processing method. Bicycles are available in Oshakati, which would cut the cost of importing foreign industrial shredding equipment. This process would be easy to implement in a dumpsite, as no external power source is needed for operation. Lastly, there are businesses in Oshakati that have spare bike parts so maintenance would be manageable.

Some disadvantages to this system are low efficiency and high user effort. For example, IWCs would need to cut plastic bottles into smaller pieces by hand and feed these pieces individually into the shredder. Pedaling does not generate constant power and it takes more time to shred plastic using a manual system rather than an electric-powered shredder. The manual system does not have the ability to process aluminum and does not have the capacity to process the full abundance of plastics in the Oshakati dumpsite, which reduces the potential profit from dumpsite processing. Additionally, dumpsite material collection is a labor-intensive job and adding mechanical processing will make it more difficult. While labor effort was not a consideration discussed by any of the stakeholders, the team recognizes its importance and will consider it when making final recommendations.

4.3.3 Industrial Processing

Industrial shredding machines are versatile and many have the ability to rapidly process LDPE, HDPE, PET, and aluminum in large quanitities. The machines that the team investigated have safety features such as protection around the blades and emergency stop buttons. One disadvantage of these types of machines is that they are not widely available in Namibia. This could make it difficult for IWCs to obtain replacement parts locally when the machine requires repairs.

Since the Oshakati dumpsite does not have access to electricity, the team investigated both diesel generators and solar panels as potential power sources for the system. Solar panels require a high initial cost but have minimal daily operation cost. A diesel generator is less expensive but requires the daily cost to fuel the machine, which would reduce IWC profits. The team chose to analyze both options in the cost-benefit analysis to determine which would result in greater monthly incomes for the IWCs over the full analysis period.

4.4 Cost-Benefit Analysis

The team conducted a cost-benefit analysis (CBA) to compare each potential process identified: a solar-powered industrial shredder, a generator-powered industrial shredder, and a manual-powered bicycle shredder. The CBA examined the industrial shredding process for plastic use, aluminum use, and a combination of plastic and aluminum use. It examined the bicycle shredding process for only plastic use, as this machine is not capable of processing aluminum. These results assume that the Oshakati IWCs would be able to collect all of the selected materials available at the dumpsite per week. Sections 4.4.1 through 4.4.5 describe how the team calculated the benefits and various costs of each process analyzed. Table 12 shows the specific equipment models the CBA evaluates in Section 4.4.6.

Table 12: CBA Processes

Machine Type	Machine Name	Power Source Type	Power Source Name	Materials Processed
Industrial Shredding Machine	German MOCO Shredding Machine AZ 09F	Solar	Solar Age Namibia SHS4 Solar Panel	Plastics and Aluminum
Industrial Shredding Machine	German MOCO Shredding Machine AZ 09F	Diesel Generator	Namibian 13 kVA Standby FAW Generator	Plastics and Aluminum
Bicycle Shredder		Manual		Plastics

4.4.1 Processing Capacity Calculation

Table 13 shows the quantity of recyclables entering the Oshakati dumpsite each week, according to the Alsins et al. 2013 study. Each week, a total of 4,620 kilograms of LDPE, HDPE, PET, and aluminum combined enter the dumpsite (Alsins et al., 2013). The total volume the 30 IWCs currently collect each week of all recyclable materials present in the Oshakati dumpsite is about 11,880 kilograms, which is greater than the 4,620 kilograms of plastics and aluminums available in the dumpsite weekly. Therefore, the project assumed that 30 IWCs would be able to collect the full available volume of these four materials. Oshakati IWCs reported that they typically work 54 hours per week, so allowing the machine to operate the full 54 hours weekly, the machine would need to process 86 kilograms per hour to maximize processing output and revenue. Thus, a small-scale industrial machine that has the capacity to process at least 86 kilograms of material per hour is most appropriate for the Oshakati dumpsite.

Table 13: Quantities of materials entering the Oshakati dumpsite weekly (adapted from Alsins et al., 2013)

Material	Quantity (kg/week)
Plastics	4,235
Aluminum	385
Plastics and Aluminum	4,620

The bicycle shredder's capacity calculation was more complex. In a video of a bicycle shredder processing plastic, a 330 milliliter bottle took about 30 seconds to shred (Shaw, 2013.) With a 330 milliliter plastic bottle weighing 0.012 kg, this bicycle shredder could process 0.024 kilograms of plastic per minute. This data suggests that the bicycle shredder can process 12.96 kilograms of plastic in a nine-hour day and 77.76 kilograms of plastic in a six-day week.

4.4.2 Benefits Calculation

The team calculated the benefits of processing the Oshakati dumpsite's plastics (LDPE, HDPE, and PET), aluminum, and plastics and aluminum combined. The team calculated the revenue from each material by multiplying Wilco's selling price to South Africa for each material by the quantity of the material delivered to the dumpsite per week. The team then multiplied this weekly profit by 52 weeks to comprise the annual profit of the material. Table 14 shows the estimated annual revenue of the materials analyzed. Since these revenues account for value of materials only after baling, they are, in effect, lower-bound revenue estimates.

Table 14: Estimated annual revenue for the industrial shredder by material

Material	Annual Revenue
Plastics	N$554,715.20
Aluminum	N$260,260.00
Plastics and Aluminum	N$814,975.20

Note that the benefits analysis uses annual revenue generated through processing rather than annual profits. The analysis does not factor in expenses such as transportation of shredded materials to customers. Also note that the bicycle shredder annual revenue does not match the full annual revenue of processed plastics. The 77.76 kilograms of plastic per week that the bicycle shredder can process is just 1.8% of the 4,325 kilograms of potential plastics that can be processed per week. Therefore, the annual revenue for the bicycle shredder is estimated at 1.8% of the potential revenue from processing all available plastic in the Oshakati dumpsite.

4.4.3 Initial Machine Cost Calculation

The team received a price quote (refer to Appendix P) from a German machine manufacturing company, MOCO Shredder, for an industrial shredding machine, the MOCO Shredding Machine AZ 09F. The team contacted this company in particular because Germany has a reputation for its high-quality machinery and they are able to easily ship goods to Namibia. The team chose the model type because it is a low-cost machine that can shred 150 kilograms per hour, which is greater than the minimum capacity of 86 kilograms per hour as calculated in Section 4.4.1. Table 15 shows the full details of the chosen industrial shredder. To estimate the initial cost of the manual-powered bicycle shredder, the team used the cost of the 2014 Recycle by Bicycle prototype, as both are bicycle-powered and require design engineers to manufacture the unique designs. Table 16 displays the initial machine cost estimates.

Table 15: Industrial MOCO Shredder Machine AZ 09F details

Price	N$330,000
Processing Capacity	150 kg/h
Drive	7.5 kW
Power Supply	400 V - 50 Hz

Table 16: Initial machine costs

Machine	Initial Cost
Industrial Shredder	N$330,000.00
Bicycle Shredder	N$6,692.50

4.4.4 Power and Fuel Cost Calculation

The team chose to investigate two power sources for the industrial shredder based on the availability of the machines and the capacity, the Solar Age Namibia SHS4 solar panel kit and the Generator King 13.2 kVA Standby FAW generator. Both of these options are the smallest and least-expensive models that meet the power capacity rating of the MOCO Shredding Machine AZ 09F (refer to Table 15 for power rating details). Table 17 displays the product specifications of the solar panel and Table 18 displays the specifications of the generator. Furthermore, Appendices Q and R show the price quotes and full specifications for the Generator King generator and Solar Age solar panel, respectively. The current Namibian diesel price of approximately N$11.10 per liter multiplied by the Generator King 13.2 kVA Standby FAW fuel efficiency rating of three liters per hour yielded the estimated hourly fuel cost. Note that three liters per hour is a conservative estimate for the calculations. Extrapolating across 54 operating hours per week and 52 weeks per year produces an annual diesel fuel cost of N$93,528.

Table 17: Solar Age Namibia SHS4 Solar Panel details (Solar Age Namibia, 2017)

Price	N$60,043.58
Maximum Power	10.5 kW

Table 18: 13.2 kVA Standby FAW Generator specifications (GeneratorKING, 2017)

Price	N$77,900
Fuel Source	Diesel
Fuel Capacity	180 L
Fuel Efficiency	3 L/h
Maximum Power	13.2 kW

4.4.5 Maintenance Cost Calculation

As Section 3.2.4 explains, the team used a publication entitled "Commodity Costs and Returns Estimation Handbook" that investigates change in maintenance and repair costs for various machine types as a function of operating times and initial machine cost. The following formula estimates the total accumulated maintenance and repair costs for machinery:

$$Total\ Accumulated\ Repair\ Cost = R_1 * P_0 * \left(\frac{H}{1000}\right)^{R_2},$$

in which R_1 and R_2 are experimentally determined repair factors specific to each machinery type, P_0 is the initial machine cost, and H is the total accumulated operating hours (Agricultural & Applied Economics Association, 2000). To estimate the annual maintenance and repair costs over the 11-year CBA period for the MOCO Shredding Machine AZ 09F and bicycle shredder, the team used the repair factor values for a rectangular baling machine, as supplied by the handbook; experimental values for the repair factors of an industrial shredding machine are not currently available. The R_1 and R_2 repair factors for this machine are 0.23 and 1.8, respectively (Agricultural & Applied Economics Association, 2000). Since the CBA calculates revenue from baling materials, the repair factors for a rectangular baling machine are a suitable representation of the maintenance and repair costs incurred from this process.

4.4.6 Cost-Benefit Analysis Results

The team conducted a CBA for each of the following potential systems for the Oshakati dumpsite:

1. One generator-powered industrial shredder processing all available plastics;
2. One generator-powered industrial shredder processing all available aluminum;

3. One generator-powered industrial shredder processing all available plastics and aluminum;
4. One solar-powered industrial shredder processing all available plastics;
5. One solar-powered industrial shredder processing all available aluminum;
6. One solar-powered industrial shredder processing all available plastics and aluminum;
7. One manual-powered bicycle shredder processing plastics.

Note that the analysis evaluates the bicycle shredder for processing plastics only. This is because the bicycle is not capable of shredding aluminum. The CBA evaluated each process over an 11-year period, including a one-year payback period for the initial costs in the first evaluation year. Throughout the analysis period, the CBA assumes that the IWCs are responsible for maintenance and fuel costs, and deducts these annual operational expenses from the IWCs' calculated revenue. For each system, the CBA returns a cost-benefit ratio and monthly profit per IWC (assuming the number of IWCs remains constant at 30) for both the first payback year and the average over 11 operational years. Table 19 summarizes the results of the seven CBAs. The full CBA results for the selected processes can be found in Appendix S.

Table 19: CBA results

Machine Type	Power Source	Material Processed	First Year Cost Benefit	11 Year Cost-Benefit Ratio	First Year Profit Per Month Per IWC	Average Monthly Profit Per IWC in First 11 Years
Industrial Shredder	Solar	Plastic & Aluminum	2.06	10.92	N$1,164.38	N$2,056.49
Industrial Shredder	Generator	Plastic & Aluminum	1.61	4.59	N$854.25	N$1,770.64
Industrial Shredder	Solar	Plastic	1.40	7.43	N$441.44	N$1,333.55
Industrial Shredder	Generator	Plastic	1.09	3.23	N$131.31	N$1,064.25
Industrial Shredder	Solar	Aluminum	0.66	3.49	-N$376.49	N$515.61
Industrial Shredder	Generator	Aluminum	0.51	1.52	-N$686.63	N$246.32
Bicycle Shredder	Manual	Plastic	1.5	7.95	N$9.43	N$24.73

All processes proved to generate a profit for the IWCs over the 11-year period. Note that the cost-benefit ratio is not the strongest indicator of the effectiveness of the system; the average monthly profit per IWC over the 11-year period most accurately reflects the system's ability to increase IWC earnings. For example, despite yielding the second-greatest cost-benefit ratio, the bicycle shredder produces the smallest profits per IWC over the 11-year period. Generating just N$24.73 per IWC per month, this bicycle system does not effectively raise IWC earnings above the current monthly average of N$528. Similarly, shredding aluminum alone does not raise earnings above the current average in either the solar or the generator-powered case. Furthermore, shredding just aluminum would leave the IWCs in a deficit for the first-year payback period. Therefore, these three systems do not achieve the project goals.

The industrial shredder processing just plastic or processing plastics and aluminum, regardless of power source, results in greater earnings for IWCs over the 11-year period than the current average. These results demonstrate that shredding plastic with an industrial machine is a viable method of increasing IWC earnings. Furthermore, using one industrial shredder to process both plastic and aluminum produces the largest potential earnings for IWCs, up to 290% greater than the current average in the solar-powered case. Despite the larger initial cost of the solar kit, the solar-powered option proved to be more profitable than the generator-powered option both in the first year and across the entire 11-year analysis period. All three solar-powered systems are more cost-effective (demonstrate a greater cost-benefit ratio) than their respective generator-powered systems.

4.5 Operational Strategies Analysis

This section describes the analysis of information provided by the stakeholders with respect to potential business strategies for a recycling processing system in Oshakati. The business strategy includes aspects regarding the management and organization of the recommended system. The combination of the initial investment and daily operational strategies will serve as the business model.

4.5.1 Important Considerations for Business Strategies

The coded interview notes revealed that the four most important considerations for the business model of the recommended system, as expressed by project stakeholders, are:

1. IWCs should be self-organized. They should delegate responsibilities amongst themselves.

2. The OTC should provide supervision for the system. The OTC could set regulations on various aspects of the system, such as safety equipment, that the IWCs do not have the authority to enforce.
3. Any equipment/machinery involved in this system should be owned and maintained by the IWCs, as opposed to the OTC, private packaging companies, or any other entity.
4. The OTC must provide training programs to ensure proper and safe operation of machinery.

Table 20 shows which operational strategy aspects each project stakeholder considers to be important to the success of the system.

Table 20: Considerations for business strategies as expressed by stakeholders

	Self-Organized	OTC Supervision/ Regulation	Self-Owned	Training Programs
Oshakati IWCs	✓	✓	✓	✓
OTC	✓	✓	✓	✓
Ongwediva IWCs	✓			
Ondangwa IWCs	✓			
RAD				
Wilco				

4.5.2 Funding

As described in Sections 4.4.3 and 4.4.4, the initial investments of the systems are as follows:

1. N$6,692 for the bicycle shredder;
2. N$390,043 for the solar-powered MOCO Shredding Machine AZ 09F;
3. N$407,900 for the generator-powered MOCO Shredding Machine AZ 09F.

During interviews, the IWCs indicated an interest in purchasing the machines with their own funds. According to the CBA, the IWCs would be able to pay off the entire initial equipment investments in one year and still generate a profit, except for the cases in which they process aluminum only. In all cases, the systems would generate enough revenue for the IWCs to earn a profit in addition to funding the annual operational costs throughout the 11-year analysis period. Additionally, for both the solar and generator-powered cases of processing plastics and aluminum, the IWCs could fully subsidize the investment in the first year of operation as well as all subsequent operational costs and still earn more than their current average monthly income throughout the analysis period. Therefore, the IWCs themselves are a potential source of funding for the system.

A second potential source of funding is the OTC. The OTC currently owns the dumpsite and has authority over all operations there. The OTC has an annual budget allocated to waste management, which, according to a 2014 study by Mughal et al., often exceeds the annual expenditure. Table 4 in Chapter 2 details the annual budget between the years of 2009 and 2014. This table shows that, over this five-year period, the annual waste management budget surplus ranged from N$300,000 to N$1,200,000, with an average of N$680,000 (Mughal et al., 2014). In all five years, this surplus exceeded the estimated annual operational costs for all seven potential systems, suggesting that the OTC has the resources to fund the system operations. Furthermore, the average surplus exceeds the combined cost of the first-year operational expenses and initial equipment investment. Additionally, the OTC stated during the discussion meeting that they could apply for federal grants to purchase processing equipment at no cost to the town or IWCs. This indicates that the OTC is a viable source of funding for the processing system.

4.5.3 IWC Organization

IWCs from all three dumpsites as well as the OTC emphasized that the IWCs themselves need to be responsible for determining their own organizational structure in the processing system. The IWCs want to be able to divide the collecting, sorting, and processing labor amongst themselves, as well as establish their own payment structure. During the focus group meeting, Oshakati IWCs developed two preliminary ideas for the processing operations. Section 4.1.2 describes the structures of these two options.

According to the stakeholder considerations table for operational strategies (Table 20 in Section 4.5.1), the most important business aspect of the proposed system is that it is self-organized. Throughout the OTC discussion, several town officials stressed that the government should not control the organizational structure, rather this should be a “community-based activity." In order to gain the support of the IWCs and the OTC, the proposed system must allow the IWCs to determine their own operational structure.

4.5.4 Management

During the discussion, the OTC indicated that they would like to be more involved in the operations at the dumpsite. The OTC does not currently station any officials in the dumpsite to oversee IWC operations. IWCs want training programs and protective gear to ensure proper and safe operation of any processing equipment. The OTC offered to coordinate training programs and provide protective equipment to the IWCs. The OTC could appoint or contract a non-IWC representative responsible for organizing training programs and monitoring safe working conditions at the dumpsite. This representative could also act as a liaison between the IWCs, the OTC, and companies that purchase the processed material. The IWCs specifically requested assistance from the OTC in ensuring fair pay from their customers.

4.5.5 Target Markets

The team investigated potential markets in Namibia to which IWCs may be able to sell their processed materials. Partnering with companies in Namibia reduces the cost of transportation and supports the local economy. The processing system should aim to sell to companies that perform further plastic or aluminum recycling processes. These companies would be able to purchase the plastic or aluminum shreds, clean them, and turn them into useful products for industry, such as plastic pellets or aluminum ingots. Plastic Packaging Polymer Recyclers is a recycling processing company located in Okahandja that produces recycled plastic pellets, and is one potential customer for this system. However, further contact must be made to determine if they are interested in working with the IWCs.

When working with recycling processing companies, the IWCs, with the help of the representative, should be able to sell shredded plastics and aluminum at prices similar to or higher than the prices at which Wilco sells baled materials. This is because the additional processing step of shredding adds more value to the materials than baling. Additionally, the IWCs may potentially be able to supplement their income from processing by continuing to collect and sell other recyclables in the dumpsite to Wilco, as time allows.

4.6 Summary

By evaluating the profitability of materials the project narrowed down the most cost-effective materials to process to be LDPE, HDPE, PET, and aluminum. Subsequent analysis identified plastic and aluminum shredding as an effective processing technique to add value to these materials. A series of CBAs evaluated manual-powered, solar-powered, and generator-powered shredding equipment for plastics, aluminum, and a combination of plastics and aluminum. These CBA results indicated which processing systems may be the most effective at increasing IWC earnings in Oshakati. From these results and input in stakeholders, the team evaluated potential sources of funding and other operational strategies for the processing system. These operational strategies are the foundation for a preliminary business model for the implementation of the processing system. Combined, these results led to the final recommendations for a small-scale recycling processing system in Oshakati, which Chapter 5 details.

CHAPTER 5: RECOMMENDATIONS AND CONCLUSION

This study investigated recycling processing techniques and potential operational strategies for a recycling processing system that could improve the earnings of IWCs in Oshakati, Namibia. Based on the results of the investigation, the team developed a set of recommendations for the town of Oshakati. These recommendations may serve as a guide to the OTC and NUST for establishing a recycling processing system for the IWCs operating in the Oshakati dumpsite.

5.1 Processing Equipment Recommendations

The team recommends that the Oshakati IWCs collect, sort, and shred Low-Density Polyethylene, High-Density Polyethylene, and Polyethylene Terephthalate plastics. Combined, these three types of plastics are the second-most abundant recyclable in the Oshakati dumpsite, and have the potential to yield the greatest profitability from processing (Alsins et al., 2013). Shredding is a simple process, and is marketable to Namibian plastic recyclers and manufacturers. The team recommends that the IWCs use a shredding machine that is also capable of shredding aluminum. Although this investigation did not identify a local market for shredded aluminum, investing in a single machine that can process both plastics and aluminum will enable greater earnings for the IWCs, should opportunities to sell shredded aluminum arise. This study suggests that shredding both plastics and aluminum in the Oshakati dumpsite has the potential to raise IWC earnings to more than triple their current state.

The MOCO Shredding Machine AZ 09F is an example of a machine the IWCs of Oshakati could use to process plastics and aluminum. This small industrial machine has the capacity to process 8,400 kilograms of material per week. This is sufficient to process the full quantity of plastics and aluminum delivered to the dumpsite, which is approximately 4,620 kilograms per week (Alsins et al., 2013). If the town is interested in using the processing system to establish a cooperative with Ongwediva and Ondangwa, a larger-scale model, such as the MOCO Shredding Machine AZ 15E, would have the capacity to process all 17,400 kilograms of plastic and aluminum generated by the three towns each week (Alsins et al., 2013). This, however, would require a larger initial investment and further study to determine the feasibility of such a cooperative three-town system.

Since the dumpsite does not have access to the Oshakati electrical grid, the team recommends that solar energy power the shredding machine. Solar panels require minimal maintenance and eliminate fuel expenses, yielding greater annual profits, despite the high initial cost. Alternatively, a less-expensive diesel generator could power the shredding machine, however this results in higher operating costs for the processing system. According to the cost-benefit analysis results, a MOCO Shredding Machine AZ 09F processing plastics and aluminum could generate N$2,056 per IWC per month if solar-powered, and N$1,771 per IWC per month if generator-powered. This suggests that the solar option could produce more than a 290% increase from the current average reported income of N$528 per month for Oshakati IWCs.

5.2 Operational Strategies Recommendations

While the cost-benefit analysis results in this report assume that the IWCs pay for the initial and operating costs themselves, their earnings would further increase if the OTC funded these expenses. To maximize earnings for IWCs, the team recommends that the OTC fund the initial equipment investment using a grant. Additionally, the OTC should own the machine and be responsible for maintenance expenses. This investigation suggests that, over an 11-year period, the maximum annual operating costs for a solar-powered industrial shredder and generator-powered industrial shredder are approximately N$67,944 and N$230,170 respectively. Both of these expenses are less than the annual Oshakati waste management budget surplus each year between 2009 and 2014, according to a waste management study by Mughal et al. in 2014. This suggests that the OTC would be able to fund these annual costs without increasing their current budget. With the assistance of OTC funding, IWCs would not need to pay back the cost of the system and could receive the full profits from processing as income. OTC funding could potentially increase the Oshakati IWCs' earnings to from N$2,056 to N$2,264 per IWC per month from processing plastic and aluminum using a solar-powered MOCO Shredding Machine AZ 09F. This represents a 10% increase from potential earnings if the IWCs were to fund all initial and operational costs, and a 330% increase from the current reported average income of N$528 for Oshakati IWCs.

Regardless of the equipment funding and ownership, both the Oshakati IWCs and OTC members stressed that the IWCs themselves should be responsible for determining their own organizational structure. The IWCs should have the power to decide how to divide the collecting, sorting, and processing labor, and how they would like to distribute pay. The IWCs already have ideas on how they might organize themselves, and doing so would empower them and encourage them to participate in the processing system.

This investigation suggests that active OTC supervision and involvement would be vital to the success of the system. The team recommends that the OTC be responsible for establishing safety regulations and performing safety inspections of the equipment. The Oshakati IWCs requested that the OTC provide free training on how to properly operate the machinery as well as free personal protective equipment, including long-sleeve shirts, gloves, and dust masks. Additionally, the team recommends that the OTC appoint a representative to monitor safety in the dumpsite, as well as to negotiate prices of processed materials and monitor sales to ensure fair and proper pay. This representative would act as a liaison between the IWCs and the companies to which they sell to assist in negotiating fair prices.

This project suggests IWCs sell their shredded plastic to Plastic Packaging Polymer Recyclers or other local recyclers and manufacturing companies. Selling to companies within Namibia reduces transportation costs and supports the local economy. Further research is needed to identify local companies to which the IWCs might sell. Since the shredding processing step adds value to the raw materials, the IWCs and the representative should be able to negotiate prices that are similar to or higher than the prices at which Wilco currently sells their baled materials. Although the team does not recommend selling the processed materials to RAD or Wilco, the IWCs should continue selling additional, unprocessed materials other than aluminum and plastic to Wilco to supplement their income from processing. After collecting all of the available plastics and aluminum each week, they may choose to also collect glass and other metals. They should focus on these two materials because recycling packaging companies offer higher prices for these than for other unprocessed recyclables. Additionally, they should sell to Wilco rather than RAD because Wilco offers higher prices.

Finally, the team recommends that the OTC provide the IWCs with a weight scale they can use at the dumpsite to measure the amounts of materials they collect, sort, and process, as well as a storage unit for their equipment. The IWCs should develop a system to record the weight of their materials so they can monitor their sales and ensure they are receiving fair payment from customers. A storage unit would protect the equipment from damage and ensure unauthorized waste collectors do not use the machinery.

5.3 Future Direction

This study suggests that shredding plastics and aluminum in the Oshakati dumpsite is a viable method for increasing the earnings of IWCs in Oshakati. While this report intends to serve as a guide for the initial planning of a local recycling processing system, further research is needed to confirm the economic feasibility and to determine the most appropriate structure for such a system. The next steps to successfully implement recycling processing in the Oshakati dumpsite are to further investigate marketability, environmental effects, operational strategies, and legal implications. This project did not identify a reliable market to which the IWCs could sell either shredded plastic or shredded aluminum. Preliminary research indicates that there are Namibian companies that may be interested in partnering with such an initiative, but the team was not able to confirm their interest or receive quotes for what these companies would be willing to pay for shredded materials. Future studies should investigate local markets to confirm potential customers and to obtain more reliable pricing data for shredded plastics and aluminum. These research efforts should also identify methods of transporting the processed materials to the customer, and determine the associated costs. This will allow for a more accurate cost-benefit analysis to better estimate the profitability of the potential processing system. Such a study is currently in progress by NUST graduate student Martha Haukena.

This investigation focused on the economic feasibility of small-scale processing in Oshakati but did not evaluate the potential environmental impacts of the recommended systems. Establishing local processing and selling to local markets would eliminate the need to transport plastics and aluminum to South Africa, thereby reducing transportation-related pollution. However, introducing an industrial shredding machine to Oshakati could produce small amounts of debris and noise pollution in the dumpsite. Further analysis of these environmental impacts is necessary to ensure that the processing system will align with the goals stated by the Environmental Management Act of 2007. Stefanus Kalangula, a Nature and Resource Management student at NUST, is in the process of evaluating the potential environmental effects of recycling processing in Oshakati.

The positive results of the economic feasibility evaluation in this project suggest that this model of small-scale recycling processing by IWCs could be adapted to other Northern Namibian towns with similar recycling structures. The team recommends that further study investigate the possibility of expanding the project to Ondangwa and Ongwediva, either through a single cooperative processing system or by implementing similar systems in these neighboring towns. This would require extensive evaluation of the laws and regulations in all three towns associated with implementing such a cooperative. Additionally, there may be regulations that restrict the involvement of a government entity in business operations. Future research must evaluate the legal framework in Oshakati and the nearby towns to determine the appropriate roles of these town councils in implementing and regulating a dumpsite recycling processing system.

5.4 Conclusion

The goal of this project was to increase the earnings of informal waste collectors in Oshakati, Namibia by recommending a recycling processing system to add value to their collected materials. By evaluating the current recycling system in Oshakati as well as potential processes and operational strategies, the team determined plastics and aluminum shredding as an effective method to increase the earnings of IWCs. The results of this investigation indicated that a small-scale, solar-powered plastics and aluminum shredding machine funded by the OTC has the potential to increase IWC monthly earnings by up to 330% from their current state.

BIBLIOGRAPHY

Agricultural & Applied Economics Association. (2000). *Commodity costs and returns estimation handbook.* Iowa: Agricultural & Applied Economics Association.

Alibaba. (2017). Fast Speed Aluminum Melting Machine. Retrieved February 22, 2017, from https://www.alibaba.com/productdetail/Fast-Speed-Aluminum-Melting-Machine_60403552562.html?s=p

Alsins, A., Sundgren, A., Shooya, R. N. M., & Nashongo, T. N. (2013). *Analysis of qualities and quantities of waste and recyclable in the Namibian towns*. Polytechnic of Namibia, Windhoek, Namibia.

AZO Materials. (2012). *Steel recycling principles and practice*. Retrieved February 22, 2017, from http://www.azom.com/article.aspx?ArticleID=7979

Bajpai, P. (2013). Recycling and deinking of recovered paper. *Elsevier Insights.* Elsevier Science.

Bing Maps. (2017). [Map of Oshana Province]. Bing. Retrieved February 12, 2017, from http://www.bing.com/maps?osid=aea3d8c2-ef52-47e0-98b3-471c3564e501&cp=-20.583358~18.859379&lvl=6&v=2&sV=2&form=S00027

City of Windhoek. (2016). Solid Waste Management Policy. Windhoek, Namibia.

Consol Glass Co. (2014). *Glass recycling*. Retrieved April 1, 2017, from http://www.consol.co.za/business/why-glass/glass-recycling

CP Manufacturing. (2012). *Glass crusher*. Retrieved February 22, 2017, from http://www.cpmfg.com/recycling-equipment/aluminum-can-recycling-machines/

Dynaform Technologies, Inc. (n.d.). [Image of a melting furnace]. Retrieved February 13, 2017, from http://www.dynaformtech.com/files/freestyle/melting-furnace.jpg

Encyclopedia Britannica. (1998). [Map of Namibia]. Retrieved January 29, 2017, from https://www.britannica.com/place/Namibia

GeneratorKING. (2017). Diesel powered generating sets. Retrieved April 18, 2017, from http://www.genking.co.za/product/13kva-standby-faw/

Green, R. H. (2016, August 26). *Namibia*. Retrieved February 04, 2017 from https://www.britannica.com/place/Namibia

Google Maps. (2017). [Map of Oshakati, Namibia]. Retrieved February 12, 2017, from https://www.google.com/maps/place/Oshakati,+Namibia/@-17.7846743,15.6506937,13z/data=!4m5!3m4!1s0x1b939f5668017833:0x7a89640ee7199772!8m2!3d-17.7894532!4d15.7057792

Haarman, A. (July 2015.) Towards sustainable plastic recycling in India: Experiences from the field. *Sustainable Recycling Industries*. Delhi, India.

Haidula, T. (15 June 2016). Keeping Windhoek clean comes at a price. *The Namibian.* Retrieved February 8, 2017, from http://www.namibian.com.na/151995/archive-read/Keeping-Windhoek-clean-comes-at-a-price

Hangula, L. (1993). *The town of Oshakati: A historical background.* Discussion Paper 9. Windhoek: Social Sciences Division, University of Namibia.

Hasheela, R. (2009). *Waste Management in Namibia: The Windhoek Case Study.* (Doctorate of Philosophy), Universidad Azteca, Chalco, Mexico. Retrieved February 5, 2017, from http://www.the-eis.com/data/literature/Municipal%20Waste%20Management%20in%20Namibia.pdf

Haukena, M. (2017). *Evaluating the effectiveness of using a bicycle cart in the collection of recyclables from households in Oshakati, Namibia* (Bachelor's mini-thesis). Namibia University of Science and Technology, Windhoek, Namibia.

Holaciudad. (2013). [Image of a bicycle pelletizer]. *Joven puertorriqueño construye una bicicleta para reciclar plastic*. Retrieved April 3, 2017, from http://www.holaciudad.com/

International Aluminium Institute, et al. (2009). Global Aluminum Recycling: A Cornerstone of Sustainable Development. Retrieved February 22, 2017, from http://www.world-aluminium.org/media/filer_public/2013/01/15/fl0000181.pdf

Investigación y Desarrollo (2015, January 4). Technology to recycle all type of plastics without using water. *ScienceDaily*. Retrieved February 4, 2017 from www.sciencedaily.com/releases/2015/01/150104152309.htm

Jacobsen A. C. G., Kelly, M. D., Roche, L. A., & White, E. T. L. (2014). *Recycling by Bicycle: A Green Alternative to Expand Recycling and Create Jobs in Windhoek* (Undergraduate Interactive Qualifying Project No. E-project-050814-115544). Retrieved January 30, 2017, from Worcester Polytechnic Institute Electronic Projects Collection: https://web.wpi.edu/Pubs/E-project/Available/E-project-050814-115544/

Made in China. (2017). *Zhengzhou Gou's Electromagnetic Induction Heating Equipment Co., Ltd.* Retreived February 22, 2017, from http://induction-heatings.en.made-in-china.com/product/QMvxhafVVjTG/China-100-KG-aluminum-Induction-Heating-Melting-Furnace-Electric-Tilting-Furnace.html

Magen, Y. (2010). Waste Management and Recycling Study in Namibia. Tampere University, Tampere Finland.

Ministry of Labor, Industrial Relations and Employment Creation. (2015). *Extension of collective agreement to construction industry labor act, 2007* (Government Notice No. 319). Windhoek, Namibia: Government Gazette of the Republic of Namibia.

Moreno-Sanchez, R. D. P., & Maldonado, J. H. (2006). Surviving from garbage: the role of informal waste-pickers in a dynamic model of solid-waste management in developing countries. *Environment and Development Economics*, *11*(03), 371-391.

Mughal, M. I., Kalumbu, H., Phillemon, M., & Tulenheimo, R. (2014). *Feasibility study on potential waste between three northern Namibian towns.* Polytechnic of Namibia, Windhoek, Namibia.

Namibia Statistics Agency. (2012a). *Poverty Dynamics in Namibia: A comparative study using the 1993/94, 2003/04 and the 2009/10 NHIES surveys.* Windhoek, Namibia: Namibia Statistics Agency.

Namibia Statistics Agency. (2012b). *Namibia 2011 population & housing census main report.* Windhoek, Namibia: Namibia Statistics Agency.

Namibia Statistics Agency. (2015). *Namibia labour force survey 2014 report.* Windhoek, Namibia: Namibia Statistics Agency.

Office of the Prime Minister. (2007). *Promulgation of Environmental Management Act, 2007 (Act No. 7 of 2007), of the Parliament* (Government Notice No. 232). Windhoek, Namibia: Government Gazette of the Republic of Namibia.

European Paper & Packaging Industries. (2017). *The paper recycling process*. PaperOnline. Retrieved February 11, 2017, from http://www.paperonline.org/environment/paper-recycling/the-paper-recycling-process

Recycle Namibia Forum. (2014). Recycling in Namibia. RNF. Windhoek, Namibia.

Rogoff, M. J. (2014). *Solid waste recycling and processing: Planning of solid waste recycling facilities and programs* (2nd ed.). Waltham, MA: William Andrew.

Shaw, D. (2013). *News: Recycling Bicycle Makes Money From Plastic.*

Solar Age Namibia. (2017). Solar home systems standard kits budgetary prices. Retrieved April 18, 2017 from http://www.solarage.com/wp-content/uploads/2014/08/SOLAR-HOME-SYSTEM-STANDARD-KITS.pdf

Total Materia. (2003, September). Aluminum and Aluminum Alloys Casting Problems. http://www.totalmateria.com/Article83.htm

Tvedten, I. (2011). *"As long as they don't bury me here": Social relations of poverty in a Namibian shantytown* (Vol. 11). Basler Afrika Bibliographien.

Tvedten, I., & Nangulah, S. (1999). *Social relations of poverty: A case-study from Owambo, Namibia*. Chr. Michelsen Institute.

Van Den Berg, S. (2009). Recycling Plastics: Starting a Business. Practical Action: Technology Challenging Poverty. Warwickshire, UK.

Vasave, N. (2013). *Recycling in India.* Amedabad, India.

The World Bank, World Development Indicators. (2017). *GDP (Current US$)* [Data file]. Retreived February 13, 2017, from http://data.worldbank.org/country/namibia

Yang, X., & Peuya, A. (2015). *Recycling by Bicycle – A profitability analysis in Ongwediva and Oshakati.* Polytechnic of Namibia, Windhoek, Namibia.

APPENDIX A: INFORMED CONSENT STATEMENT

We are a group of students from Worcester Polytechnic Institute (WPI) in Massachusetts. We are interviewing waste collectors and recycling companies to learn more about recycling collection and processes in Namibia. We hope this research will ultimately improve the local waste management system and contribute to improving the earnings of waste collectors in Oshakati.

Your participation in this interview is completely voluntary and you may withdraw at any time. Please remember that your answers will remain anonymous. No names or identifying information will appear in any of our project reports or publications.

This is a collaborative project between Namibia University of Science and Technology and WPI, and your participation is greatly appreciated. If interested, we can send you a copy of our results at the conclusion of the study.

APPENDIX B: INTERVIEW QUESTIONS FOR KUPFERBERG LANDFILL CONTRACTOR

Introduction/History of Workers

1. How long have you worked at this landfill?
2. How long have there been collectors working at this landfill?
3. How often do collectors work, in days per week and hours per day?
4. Can you walk us through a typical workday for a collector?
    a) What are some concerns you have about collectors working in the landfill?
5. What role do collectors serve to the waste management process in Windhoek?
6. What roles do different collectors have? Ex. Supervisors, collectors, sorters, etc.

Demographics

7. What is the male to female breakdown of collectors?
8. Are there any restrictions for who can work as a collector?

Current Condition/Logistics

9. What is the daily contact between collectors and the contractor?
    a) What advantages does this bring? And what challenges have occurred?
10. If you can tell us, how much of each material do collectors gather on a daily basis?
11. How do you keep track of how many recyclables the collectors have gathered and sold?
12. Which companies do sell the landfill's recyclables to?
    a) Do you have any contracts in place with these companies?
    b) Which company do you prefer to sell the landfill's recyclables to?
        1. Why this company?
13. How are you and the collectors compensated for the materials that you sell to this company?
14. How much does this company pay for recyclables?
    a) Price of paper?
    b) Price of cardboard?
    c) Price of plastics?
    d) Price of glass?
    e) Price of metals?
    f) Price of any other materials collected?
15. What changes have you seen in the waste management and recycling system since you have been working at the landfill, particularly in terms of payments or collection strategies?
16. Have you ever considered changing anything about the recycling collection process?
    a) If so, what ideas have you had?
    b) Have you tried implementing them?
    c) What has been successful, and what has not worked?

17. What improvements to the recycling process could benefit you?
18. What are some challenges you have experienced in the current recycling system?

Our Study

[Briefly introduce the idea of the project. Provide examples of small-scale processes.]

19. Do you have any suggestions as to what materials might be the most available to process?
20. Would processing materials locally add value to them?
21. What should we keep in mind when designing a processing system?

APPENDIX C: INTERVIEW QUESTIONS FOR INFORMAL WASTE COLLECTORS

B.1 Ongwediva Informal Waste Collectors

Introduction/History of Workers

1. How long have you worked at this dumpsite?
2. How long have there been collectors working at this dumpsite?
3. How often do you work, in days per week and hours per day?
4. What does a typical workday include?
5. What roles do different collectors have? Ex. Supervisors, collectors, sorters, etc.

Demographics

6. How many collectors are operating at this dumpsite?
7. What is the male to female breakdown of collectors?
8. Are there any restrictions for who can work as a collector?

Current Condition/Logistics

9. If you can tell us, how much of each material do you collect on a daily basis?
    a) Paper?
    b) Cardboard?
    c) Plastics?
    d) Glass?
    e) Metals?
    f) Any other materials collected?
10. How do you keep track of how many recyclables you have collected and sold?
11. Which companies do sell your recyclables to?
    a) Do you have any contracts in place with these companies?
    b) Which company do you prefer to sell your recyclables to?
        1. Why this company?
12. How are you compensated for the materials that you sell to this company?
13. How much does this company pay for recyclables?
    a) Price of paper?
    b) Price of cardboard?
    c) Price of plastics?
    d) Price of glass?
    e) Price of metals?
    f) Price of any other materials collected?
14. How and how often do you get paid?

15. What changes have you seen in the waste management and recycling system since you have been working as an informal waste collector, particularly in terms of payments or collection strategies?
16. Have you ever considered changing anything about the recycling collection process?
    a) If so, what ideas have you had?
    b) Have you tried implementing them?
    c) What has been successful, and what has not worked?
17. What improvements to the recycling process could benefit you and other collectors?
18. What are some additional concerns you have about working in the dumpsite?

Our Study

[Briefly introduce the idea of the project. Provide examples of small-scale processes.]

19. What are your thoughts about working in a local recycling processing system?
    a) Would you be interested in partnering in such a system?
    b) What role would you like to play in this system?
20. Do you think maintaining a processing system will be an issue?
21. What should we keep in mind when designing a processing system? Are there any necessary skills and knowledge that you would like to highlight?
22. Do you think other collectors would be interested in working in a processing system?
23. Overall, what do you foresee as the advantages and disadvantages of such a system?

B.2 Ondangwa Informal Waste Collectors

Introduction/History of Workers

1. How long have you worked at this dumpsite?
2. How long have there been collectors working at this dumpsite?
3. How often do you work, in days per week and hours per day?
4. What does a typical workday include?

Demographics

5. How many collectors are operating at this dumpsite?
6. What is the male to female breakdown of collectors?
7. Are there any restrictions for who can work as a collector?

Current Condition/Logistics

8. If you can tell us, how much of each material do you collect on a daily basis?
9. Do you weigh the recyclables that sell?
10. Which companies do sell your recyclables to?
    a) Which company do you prefer to sell your recyclables to?
        1. Why this company?
11. How are you compensated for the materials that you sell to this company?
12. How and how often do you get paid?

13. Have there been any changes since you have been working as a collector, in terms of payments or collection strategies?
14. What are some additional concerns you have about working in the dumpsite?
15. What improvements to the recycling process could benefit you?

Our Study

[Briefly introduce the idea of the project, provide examples of small-scale processes]

16. What are your thoughts about working in a local recycling processing system?
    a) Would you be interested in baling or processing materials?
    b) Would you be comfortable operating these machines?
17. What concerns do you have about baling or processing materials at the dumpsite?
18. Do you have any final thoughts or questions for us?

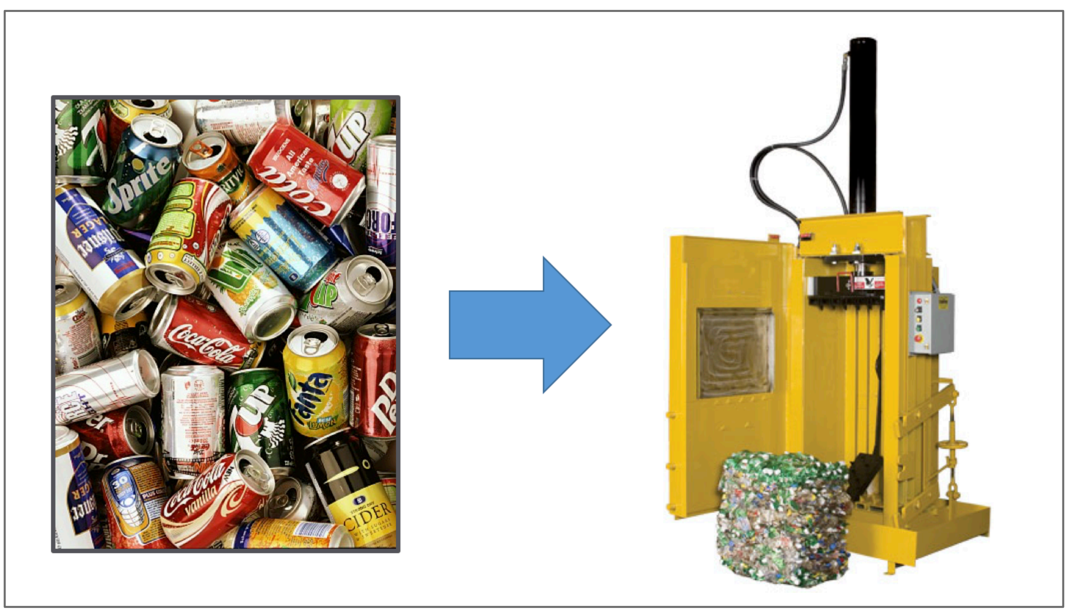
B.3 Oshakati Informal Waste Collectors

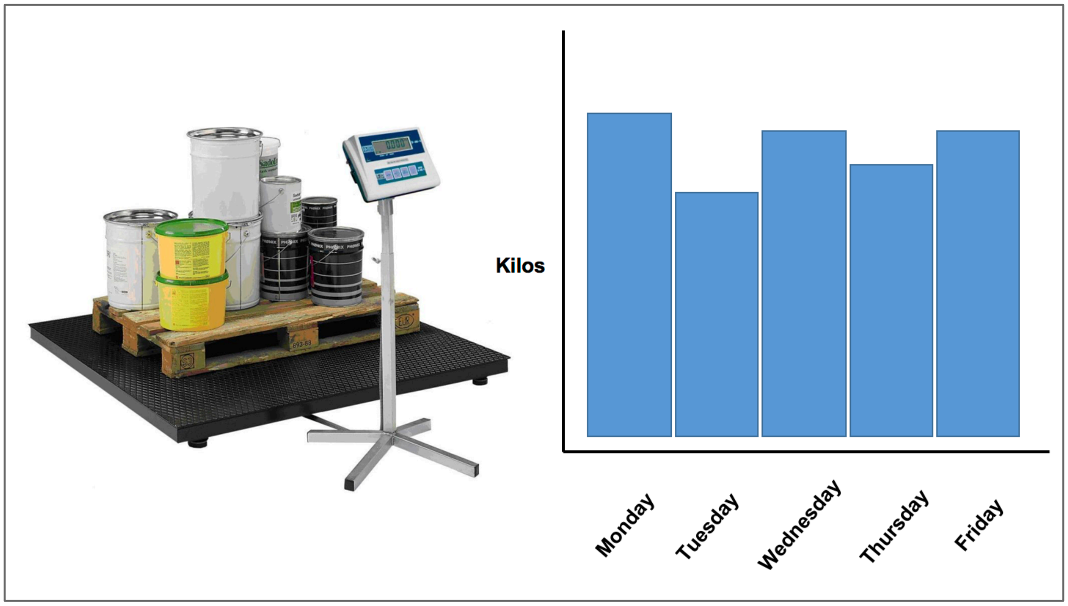
Agenda for the Feedback Meeting

1. IWCs will be provided with free transportation to the meeting.
2. Ask a volunteer IWC to provide an opening prayer (as per local customs).
3. Introduction and welcome by an OTC official.
4. Introductions:
    a) IWCs introduce themselves: share their name, the number of years they have been working at the dumpsite, whether or not they have heard of the Recycle by Bicycle project.
    b) Team members and sponsors introduce themselves.

5. Ms. Haukena will talk about the Recycle by Bicycle project and the results of the 2016 Oshakati trials.
6. Open discussion: opinions on the Recycle by Bicycle project and concerns or comments about their current working conditions in the dumpsite.
7. Present six challenges of working as an IWC that the team identified through research and prior interview responses. The six challenges (listed below) will be written in Oshiwambo and posted on a pin board. Each IWC will be given three stickers, which they will be asked to place on the challenges they believe are most prevalent.
    1. Pay is too low;
    2. Cannot bale or weigh materials themselves;
    3. Long hours in the sun;
    4. Not enough protective equipment;
    5. The selling prices never change;
    6. No proof of weight using scale.

8. The results of the prior activity will be discussed and the IWCs will be asked to think of and write down on note cards some ideas for how to improve their current working conditions. These cards will be collected and read aloud to the group so they can be discussed.
9. Ms. Haukena will introduce the current project and present preliminary ideas for processes, identified by the team. The team developed visuals to visually represent the processes, and Ms. Haukena explained each visual to the IWCs. The visuals the team developed for these processes are shown below:




Kilos
Monday
Tuesday
Wednesday
Thursday
Friday

10. Open discussion: opinions on the project, including:
    a) Potential business strategies;
    b) Potential obstacles;
    c) If they would still want to work with RAD and Wilco;
    d) Willingness to participate;
    e) What roles they see themselves playing in this system.
11. Conclusions and thanks.
12. The OTC will provide a free lunch to all IWCs in attendance.

APPENDIX D: INTERVIEW QUESTIONS FOR RECYCLING PACKAGING COMPANIES

Current Operations

4. Can you please tell us about your company and the work that you are involved in?
5. What role does your company play in the local waste management and recycling system?
    a) What towns do you provide service for?
6. Where do the materials that you process come from?
    a) Who collects these materials for you?
    b) What is your relationship with these suppliers/collectors?
7. What quantities of recyclables, in weight, do you collect per month for each type of material?
    a) About how much of this is purchased from informal waste collectors in dumpsites?
    b) About how much of this comes from each town?
8. What types of recycling processing does your company perform?
9. Where do you send your processed materials?
    a) What further processing is performed there?
    b) What expenses do you incur from your operations, such as product transportation?
10. What improvements to the local recycling system would benefit your company?
11. Have there been any attempts to improve the recycling system within your company?
    a) Who initiated these changes?
    b) What has worked and what has not?

Our Study

[Briefly introduce Recycle by Bicycle.]

12. Do you support the Recycle by Bicycle initiative?
    a) Why or why not?

[Briefly introduce the idea of processing recyclables locally.]

13. What do you foresee as the role of your company if such a local recycling processing system was established in Oshakati?

APPENDIX E: PRESENTATION AND DISCUSSION QUESTIONS FOR OSHAKATI TOWN COUNCIL

Recycling by Bicycle: A Green Alternative to Expand Recycling and Create Jobs in Oshakati, Namibia

WPI

William Bennett
Emily Chretien
Sophia Gomarlo
Peter Hurley
Stefanus Kalangula

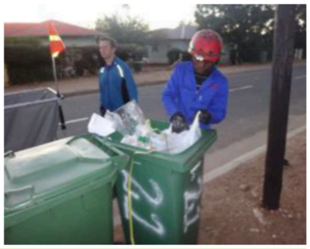
NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY

Project Aim

To contribute to **improved livelihoods** of informal waste collectors through the **creation of green, reliable jobs** and a secondary industry in designing of low cost transport systems in the recycling industry. Consequently a **clean environment**.

Progress Thus Far

Pilot Collection in Windhoek, 2014



Disposal Site Collection	Bicycle Collection at the Source
N$8.46 per hour	N$8.77 per hour

Progress Thus Far

Pilot Collection in Oshakati East and Oshakati West, 2016

Disposal Site Collection	Bicycle Collection at the Source
N$1.06 per hour	N$1.81 per hour

Our Project

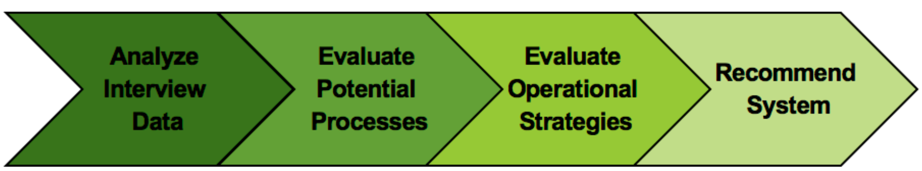
Investigating a Small-Scale Recycling Processing System for the Informal Waste Collectors of Oshakati

Mission

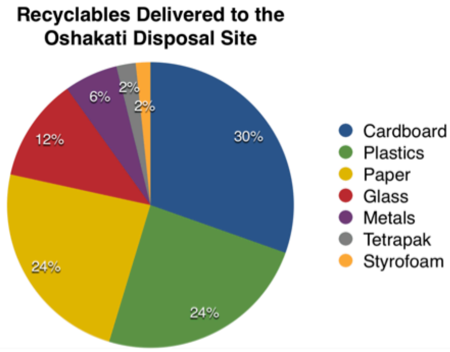
The goal of this project is to **improve the earnings** and livelihoods of **informal waste collectors** in Oshakati, Namibia by integrating them into a restructured **recycling processing system**.

Data Collection

Methodology



Available Materials



Data from NUST 2013 Waste Analysis Study (Alsins et al.)

Small-Scale Processing

- Small material volume
- Simple process
- Minimal employee training
- Low energy use
- Mobile, able to be used directly in the disposal site

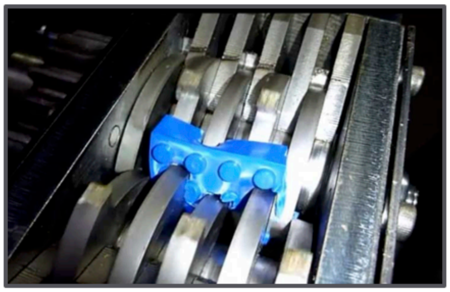
Weighing and Baling

Glass Processes

Current Method

Potential Method

Plastic Processes



Shreds

Pellets

Alternative Energy Sources

Alternative Energy Sources

Expected Outcome

- Propose an appropriate recycling process
  - Processing technology
  - Business model

Expected Impact

- Increase the earnings of Informal Waste Collectors
- Promote a clean town
- Support the local economy

Discussion and Questions

Questions

Would you support such an initiative?

Questions

How do you envision such a system to be managed and operated?

- Who should be involved?
- What would be the role of the Town Council?
- What organizational structure would you recommend? Contract? Corporative? Current Method?

Questions

Overall, what are some of the key considerations to ensure a successful system?

Acknowledgements

- Oshakati Town Council Members
- Namibia University of Science and Technology
  - Mr. Lameck Mwewa
  - Ms. Clarence Ntesa
- Worcester Polytechnic Institute
  - Professor Robert Kinicki
  - Professor Sarah Wodin-Schwartz

Thank You!
Questions?

APPENDIX F: QUESTIONS FOR MANUFACTURERS/POTENTIAL CUSTOMERS

F.1 Email to Manufacturing Companies

We are a group of students working with Namibia University of Science and Technology to study the recycling system in Namibia. Specifically, we are investigating possible ways to improve recycling in Oshakati, Namibia. Currently in Oshakati, recyclables are collected from the town waste disposal site and sold to Rent-a-Drum and other private companies, who bale the materials and sell them to external recycling and manufacturing plants. We are studying the possibility of developing a small-scale recycling processing system in Oshakati that could take collected materials and prepare them for manufacturing use. We are surveying Namibian manufacturing companies to gauge interest in partnering with such an initiative.

At this time, we are not implementing any changes to the recycling process. We are conducting research to examine the potential for recycling processing in Oshakati. We understand that you may not be able to answer all of the following questions, and we appreciate any information and assistance you can offer us.

1. What materials does your company use for your plastics manufacturing?
    a) Do you use any recycled materials in your manufacturing? If so, what percentage of your materials are recycled?
    b) In what form do you purchase these materials? (Examples: chipped plastic, plastic pellets, baled plastics.)
    c) From whom do you purchase these materials? How are they transported from the supplier to the manufacturing location?
    d) How much do you pay for these materials?
    e) What volume of material do you purchase?
    f) How do you ensure the quality of the material that you purchase?

2. Assuming the supply to be constant and sufficient, would your company be interested in purchasing locally supplied recycled materials for your manufacturing? Why or why not?
    a) What requirements (material form, quality, volume, price) would this supplier need to meet in order for you to consider purchasing from them?
    b) How could a small-scale recycling processing system in Oshakati could benefit your company?

F.2 Email to Recycling Processing Companies

We are a group of students working with Namibia University of Science and Technology to study the recycling system in Namibia. Specifically, we are investigating possible ways to improve recycling in Oshakati, Namibia through small-scale community recycling initiatives.

At this time, we are not implementing any changes to the recycling process. We are conducting research to examine the existing recycling system. We understand that you may not be able to answer all of the following questions, and we appreciate any information and assistance you can offer us.

1. What recycled materials does your company purchase?
    a) In what form do you purchase these materials? (Examples: baled, crushed, chipped.)
    b) From whom do you purchase these materials? (Especially Namibian suppliers)
    c) How are the materials transported from the supplier to the your location?
    d) How much do you pay for these materials?
    e) What volume of material do you purchase?
    f) How do you ensure the quality of the material that you purchase?

2. Do you currently, or would you be interested in, purchasing materials from small-scale suppliers in Namibia? Why or why not?
    a) What requirements (material form, quality, volume, price) would this supplier need to meet in order for you to consider purchasing from them?

APPENDIX G: COST-BENEFIT ANALYSIS SPREADSHEET

Material

Machine Type	*Fiscal Year*											
Costs	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
Initial Machine Cost												
Maintanance Cost												
Total												

Benefits	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
Profit												
Total												

Analysis	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
Cost-Benefit Ratio												

Per Person Analysis	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Average**
Profit per IWC												
Profit per month per IWC												

APPENDIX H: INTERVIEW RESPONSES FROM KUPFERBERG LANDFILL CONTRACTOR

Date: 22 March 2017, 12h00
Interviewers: Peter Hurley (facilitated), Stefanus Kalangula (asked additional questions related to his project), William Bennett (took notes), Emily Chretien (took notes), Sophie Gomarlo (took notes)
Interviewee: Kupferberg Landfill Contractor (anonymous)

Introduction/History of Workers

1. *How long have you worked at this landfill?*
   The contractor has been working at the landfill for 11 years.
2. *How long have there been collectors working at this landfill?*
   The number of years varies across the workers. For example, one anonymous collector has been working in the landfill for five years.
3. *How often do collectors work, in days per week and hours per day?*
   Collectors work six days per week, and 8 to 9 hours per day.
4. *Can you walk us through a typical workday of a collector?*
   The contractor explained that in the morning, landfill employees spread out the delivered waste so collectors can extract as many recyclable materials as possible. In the afternoon, the workers sort the recyclables into designated bags or bins to be sent to RAD. The contractor added that the collectors work in small groups. Each group focuses on a particular material to collect and sort.
   a) *What are some concerns you have about collectors working in the dumpsite?*
      The contractor did not express any prominent concerns.
      The contractor stated that he supplies collectors with personal protective equipment, including gloves. All workers undergo yearly medical inspections. Landfill security officers only allow official employees into the landfill for safety reasons.
5. *What role do collectors serve to the waste management process in Windhoek?*
   Collectors take recyclables out of the city landfill to sell to RAD. This reduces waste in the landfill and generates income for the contractor.
6. *What roles do different collectors have? Ex. Supervisors, collectors, sorters, etc.*
   According to the contractor, one collector is in charge of dividing the collectors into groups for sorting materials. Men often work with glass and heavier materials. No other roles are apparent.

Demographics

7. *What is the male to female breakdown of collectors?*
   There are 18 female and 4 male collectors.

8. *Are there any restrictions for who can work as a collector?*
   Employees must be at least 18 years old, as per labor laws.

Current Condition/Logistics

9. *What is the daily contact between collectors and the contractor?*
   All collectors operating in the landfill are official employees of the contractor. The contractor said he trusts the collectors to do their jobs and does not supervise closely. He expressed a positive relationship with his workers.
   a) *What advantages does this bring? What challenges have occurred?*
      The contractor did not express any challenges with this system. He added that the landfill is monitored by video surveillance if a problem was to occur.
10. *If you can tell us, how much of each material do the collectors gather on a daily basis?*
    7,000 tons of waste enters the landfill each month. The collectors gathered 181 tons of recyclables last month, including 10 tons of steel and 51 tons of glass. The contractor emphasized that this is an improvement over the previous landfill contractor, who collected only 50 to 60 tons of recyclables per month. The collectors gather and sell steel, papers, PET bottles, HDPE, LDPE, cardboard boxes, glass, and Tetrapak cartons.
11. *How do you keep track of how many recyclables the collectors have gathered and sold?*
    The contractor weighs the RAD trucks filled with recyclables before they leave the dumpsite, and RAD weighs them again when they enter the RAD facility.
12. *Which companies do you sell the landfill's recyclables to?*
    The contractor sells most materials to RAD. Additionally, he sells LDPE to Namibia Polymer Producers, and aluminum that is not from cans to two small, local recyclers.
    a) *Which company do you prefer to sell the landfill's recyclables to?*
       The contractor sells most materials to RAD.
       1. *Why this company?*
          According to the contractor, RAD is the largest company with the most resources and they are very reliable with payment. RAD pays for the transportation of material from the landfill to their facility.
13. *How are you and the collectors compensated for the materials that you sell to this company?*
    RAD pays the contractor based on weight of each material collected. The contractor pays collectors minimum wage on a weekly basis (N$16.04 per hour). Additionally, the contractor provides free and safe transportation to and from the landfill for employees.
14. *How much does this company pay for recyclables?*
    The contractor supplied the price list shown below via email following the interview:

Price List per commodity

Commodity	Tons		Price per Ton
Cans - Aluminium per ton	1.00		N$2,500.00
Cans- per- ton	1.00		N$450.00
Carton - K4 per ton	1.00		N$180.00
HDPE Pet Clear – Bottles per ton	1.00		N$421.63
LDPE -Mix - Plastic – Soft per ton	1.00		N$270.00
LDPE -Plastic- Clear per ton	1.00		N$421.63
Mix - Glass- per ton	1.00		N$120.00
Paper - Flatnews per ton	1.00		N$100.00
Paper -Supermix -per ton	1.00		N$300.00
Plastic – HDPE Plastic Bottles - per ton	1.00		N$421.63
Plastic -Pet Mix bottles per ton	1.00		N$390.00

RENT-A-DRUM

15. *What changes have you seen in the waste management and recycling system since you have been working at the landfill, particularly in terms of payments or collection strategies?*
    RAD provided the landfill with bins for on-site sorting of recyclables.
16. *Have you ever considered changing anything about the recycling collection process?*
    The contractor did not express any ideas.
    a) *If so, what ideas have you had?*
       [not applicable]
    b) *Have you tried implementing them?*
       [not applicable]

c) *What has been successful, and what has not worked?*
   The contractor called over an anonymous collector, who emphasized that the job relies on "hard work."

17. *What improvements to the recycling process could benefit you?*
    The contractor is currently losing money by selling materials to RAD. He is looking at other options for increasing the value of the materials his employees collect.
18. *What are some challenges you have experienced in the current recycling system?*
    The contractor expressed that he is not satisfied with the prices RAD offers.

Our Study

19. *Do you have any suggestions as to what materials might be the most available to process?*
    Cardboard is the most abundant recyclable material by volume in Windhoek. Glass is second.
20. *Would processing materials locally add value to them?*
    The contractor believes there is potential to do some preliminary processing right at the landfill and selling to companies other than RAD. He is considering crushing glass at the landfill and selling to private glass recyclers for N$800 per ton, instead of to RAD for N$120 per ton. He is also considering selling aluminum and steel to Collect-a-Can. If he can collect 10 tons per month, Collect-a-Can will supply the contractor with a free baling machine.
21. *What should we keep in mind when designing a processing system?*
    The contractor is not confident that there are enough materials for local processing to be profitable. He believes that the capital investment is too high for the material supply.
    He added that a new processing facility would need to be able to compete with RAD and have a suitable market for selling materials.

APPENDIX I: INTERVIEW RESPONSES FROM ONGWEDIVA INFORMAL WASTE COLLECTORS

Date: 28 March 2017, 14h30
Interviewers: Sophie Gomarlo (facilitated), Stefanus Kalangula (translated), William Bennett (took notes), Emily Chretien (took notes), Peter Hurley (took notes), Robert Kinicki (observed)
Interviewees: 5 anonymous IWCs

Note: All responses are paraphrased from the translations Mr. Kalangula provided the team.

Introduction/History of Workers

1. *How long have you worked at this dumpsite?*
   Answers ranged from 2 to 7 years.
2. *How long have there been collectors working at this dumpsite?*
   There have been IWCs operating at the dumpsite for 7 years.
3. *How often do you work, in days per week and hours per day?*
   IWCs operate five or six days a week (Monday through Friday or Monday through Saturday) from 06h00 to 19h00.
4. *What does a typical workday include?*
   IWCs sort through the dumpsite and pick out as many recyclable materials as possible. Each collector has his or her own separate area to sort the materials they gather. The collectors also smash glass bottles by hand.
5. *What roles do different collectors have? Ex. Supervisors, collectors, sorters, etc.*
   There is one collector who acts as the leader. Everyone collects and sorts their own recyclables; there are no set daily assignments.

Demographics

6. *How many collectors are operating at this dumpsite?*
   There are eight collectors.
7. *What is the male to female breakdown of collectors?*
   They are all female.
8. *Are there any restrictions for who can work as a collector?*
   The town restricts who can work at the site and contracts security guards at the entrance. The town does not allow any "scavengers," only the eight women. This is for safety reasons. The eight IWCs must wear personal protective equipment including headgear, gloves, and masks when working in the dumpsite.

Current Condition/Logistics

9. *If you can tell us, how much of each material do you collect on a daily basis?*
   The IWCs do not know how much they collect.

10. *How do you keep track of how many recyclables you have collected and sold?*
    They do not keep track of the quantity of recyclables that they collect because there is no way to weigh materials at the dumpsite.
11. *Which companies do sell your recyclables to?*
    They sell to Wilco only because it is the only buyer allowed by the town at the dumpsite.
    a) *Do you have any contracts in place with these companies?*
       The town has an agreement with Wilco so that no other companies may buy material from the dumpsite.
    b) *Which company do you prefer to sell your recyclables to?*
       [not applicable]
       1. *Why this company?*
          [not applicable]
12. *How are you compensated for the materials that you sell to this company?*
    Wilco is supposed to pay each collector a set price per kilogram of each material. Wilco pays each collector separately based on his or her individual collections.
13. *How much does this company pay for recyclables?*
    The IWCs did not know how much the companies pay for different materials.
14. *How and how often do you get paid?*
    Wilco is supposed to pay each collector once per month in cash based on the total weight of materials they have collected. The collectors said that Wilco is not always on time with payments. They also say that Wilco consistently underpays them.
15. *What changes have you seen in the waste management and recycling system since you have been working as a collector, particularly in terms of payments or collection strategies?*
    The IWCs did not describe any changes.
16. *Have you ever considered changing anything about the recycling collection process?*
    They would like to be able to sell their materials for more money and at a fair price.
    a) *If so, what ideas have you had?*
       They would like to weigh and bale the materials on their own.
    b) *Have you tried implementing them?*
       One time Wilco brought a scale to weigh the materials in front of them.
    c) *What has been successful, and what has not worked?*
       The collectors do not believe the scale Wilco brought to the dumpsite was accurate.
17. *What improvements to the recycling process could benefit you and other collectors?*
    They want to be paid more for the recyclables they collect.
18. *What are some additional concerns you have about working in the dumpsite?*
    Safety and fair pay are their primary concerns.

Our Study

19. *What are your thoughts about working in a local recycling processing system?*
    a) *Would you be interested in partnering in such a system?*
    They expressed a strong interest in processing materials themselves, as long as they have a reliable purchaser. They want to consider selling to companies other than Wilco, but they are worried that there would be no reliable market to sell to, making this idea ineffective.
    b) *What role would you like to play in this system?*
    They want to do the weighing and baling of materials themselves. They would be comfortable operating machinery.
20. *Do you think maintaining a processing system will be an issue?*
    The IWCs did not comment on maintenance.
21. *What should we keep in mind when designing a processing system? Are there any necessary skills and knowledge that you would like to highlight?*
    The IWCs did not comment on necessary skills.
22. *Do you think other collectors would be interested in working in a processing system?*
    All collectors at the Ongwediva dumpsite expressed an interest.
23. *Overall, what do you foresee as the advantages and disadvantages of such a system?*
    They see this project as a potential to increase their payment and stop Wilco from taking advantage of them.

APPENDIX J: INTERVIEW RESPONSES FROM ONDANGWA INFORMAL WASTE COLLECTORS

Date: 29 March 2017, 14h30
Interviewers: William Bennett (facilitated), Clarence Ntesa (facilitated and translated), Stefanus Kalangula (translated), Emily Chretien (took notes), Sophie Gomarlo (took notes), Peter Hurley (took notes), Robert Kinicki (observed)
Interviewees: 5 anonymous IWCs and 2 anonymous IWC group supervisors

Note: All responses are paraphrased from the translations Mr. Kalangula provided the team.

Introduction/History of Workers

1. *How long have you worked at this dumpsite?*
   The IWCs have been working at the dumpsite for 3 years.
2. *How long have there been collectors working at this dumpsite?*
   IWCs have been working at the dumpsite for 3 years.
3. *How often do you work, in days per week and hours per day?*
   IWCs work Monday through Friday from 08h00 to 17h00, and Saturday from 08h00 to 12h00.
4. *What does a typical workday include?*
   They collect as much recyclable material as possible from the waste. Then they take recyclables near the entrance of the dumpsite and sort the recyclables into piles by material. Each group works together and has their own set of piles.

Demographics

5. *How many collectors are operating at this dumpsite?*
   In total there are 12 IWCs, divided into two groups of 5 and 7. Each group has a supervisor, who reports to the RAD representative but is not formally employed by RAD.
6. *What is the male to female breakdown of collectors?*
   Of those that the team interviewed, there were 5 women and 3 men. 2 of the men were the group supervisors.
7. *Are there any restrictions for who can work as a collector?*
   The group supervisors determine who can join their group as a collector.

Current Condition/Logistics

8. *If you can tell us, how much of each material do you collect on a daily basis?*
   Plastic bottles are the most commonly collected material.
9. *Do you weigh the recyclables that you sell?*
   No. RAD collects the materials and weighs them at their facility in Oshakati. If the IWCs want to know the weight of the material, they must go to the RAD facility in Oshakati.
10. *Which companies do sell your recyclables to?*
    The IWCs only sell to RAD.

a) *Which company do you prefer to sell your recyclables to?*
[not applicable]
1. *Why this company?*
RAD is the only company available to them.

11. *How are you compensated for the materials that you sell to this company?*
RAD pays each group supervisor based on weight of materials that group collected. The group supervisor divides the money between the IWCs in that group. Usually the collectors earn equal pay, unless the supervisor believes the work was shared unevenly, in which case IWCs receive different payments (determined by supervisor).
12. *How and how often do you get paid?*
RAD pays the IWCs shortly after collecting the recyclables, but usually not on the same day. When the group has collected enough materials, the supervisor calls RAD to come to the dumpsite. RAD picks up the materials approximately 4 to 5 times per month.
13. *Have there been any changes since you have been working as a collector, in terms of payments or collection strategies?*
The IWCs did not express any changes.
14. *What are some additional concerns you have about working in the dumpsite?*
IWCs do not earn enough money. They do not get paid fairly by RAD.
15. *What improvements to the recycling process could benefit you?*
The IWCs want increased pay and safety equipment.

Our Study

16. *What are your thoughts about working in a local recycling processing system?*
a) *Would you be interested in baling or processing materials?*
They are interested in processing materials themselves.
b) *Would you be comfortable operating these machines?*
They would like to recieve training on how to use the machines.
17. *What concerns do you have about baling or processing materials at the dumpsite?*
The IWCs did not express any concerns.
18. *Do you have any final thoughts or questions for us?*
If there was a processing machine in to the dumpsite, the IWCs would all work together as a team to divide the collecting and processing work.

APPENDIX K: FOCUS GROUP NOTES AND RESPONSES FROM OSHAKATI INFORMAL WASTE COLLECTORS

Date: 31 March 2017, 10h00
Interviewers: Martha Haukena (facilitated and translated), Stefanus Kalangula (translated), Clarence Ntesa (coordinated the meeting), William Bennett (took notes), Sophie Gomarlo (took notes), Peter Hurley (took notes), Lameck Mwewa (observed)
Participants: 22 anonymous IWCs from the Oshakati dumpsite

IWC Salary Data
All 22 IWCs reported their individual monthly salary in Namibian Dollars:

400
300-500
200-500
300-600
200-350
400-578
800
300-400
200-300
700
500-700
400-600
400-750
500-700
200-600
500-700
600
600
900
1500
900-1000
300

Average: N$572
Average, excluding the outlier of N$900-1000: N$528

Note: All comments are paraphrased from the translations Mr. Kalangula provided the team.

Comments on Current Operations:

- The range of years that the IWCs have been working in the dumpsite is from 2 to 20 years.
- IWCs work individually at the Oshakati dumpsite.
- The OTC employs a site manager.
- Payment received is based on how many recyclables they collect, and therefore based on how hard they work.
    - Many IWCs prefer this system because they understand that if they work harder, they will earn more money.
- IWCs have bank accounts where they put their earnings and use the money for food and shelter.
- They prefer to work with Wilco because the owner himself interacts with them instead of general employees, which is who RAD sends to the dumpsites.
    - Wilco pays better than RAD.
    - Wilco collects from the dumpsite a couple of times per month. They bring the recyclables back to their facility where they are further sorted, then weighed and baled. At the end of each month the owner of Wilco goes to the dumpsite and pays everyone in cash according to how much they collected.
    - Sometimes Wilco comes with different size bags to collect glass, but still pays the IWCs the same price, regardless of whether one bag weighs more than another.
        - Therefore, it is not necessarily beneficial for them to crush glass since the heavier weight of the bag will not earn them more money.
    - Wilco gave IWCs protective jackets and gloves in 2009.
- RAD does not collect frequently from the dumpsite, maybe twice per year. They only come to the Oshakati dumpsite if they are short on a particular material.
- Sometimes RAD or Wilco takes IWCs' materials without their consent.
- They do not like the Recycle by Bicycle project because they said it wastes time and they can collect more recyclables without using the bike.

Current Challenges

The team presented the IWCs with six challenges of their job that the team identified through research and prior interview responses. Each IWC had the opportunity to vote for three challenges they believe are most prevalent.

13. Pay is too low (24 votes)
14. Cannot bale or weigh materials themselves (15 votes)
15. Long hours in the sun (11 votes)
16. Not enough protective equipment (8 votes)
17. The selling prices never change (7 votes)
18. No proof of weight using scale (1 vote)

Ideas for Improvements:

- They want Wilco, RAD and OTC to meet and discuss prices of materials, payment process, and frequency of collection. The IWCs want to attend the meeting as well to voice their concerns.
- They want Wilco or OTC to provide them with safety equipment.
  - They received a jacket and gloves from Wilco in 2009 and nothing since. They said they are expected to purchase their own personal protective equipment.
- They would like to form some sort of workers union.
- They think Wilco does not always weigh the materials, so they want a way to ensure that the payments are fair based on weight.
- They also think Wilco takes some materials without paying, so a process that could prevent theft would be helpful.

Comments on Processing Recyclables:

- None of the IWCs have ever used a baler or any similar recycling processing machines.
  - They would, however, look forward to using such machines.
- IWCs said they would like to be the owners of the machine and responsible for maintenance.
  - They would like help from OTC with storage of the machines.
- IWCs said they do have enough money to at least help invest in the machine, however, before doing so they would like to know by how much it will increase their income.
  - They would like OTC to observe the investment to make sure the machines they get are the quality they need and the prices are fair.
- If IWCs are processing materials, they would like to establish the prices at which they sell materials to Wilco and RAD.
- Ideas for operational strategies suggested by IWCs:
  - Option 1:
    - One trained person operates the machine;
    - All other IWCs give their materials to that person to process;
    - Everyone gives a portion of their pay to the trained operator for their work;
    - If there are multiple machines, use the same strategy with multiple trained operators.
  - Option 2:
    - IWCs split into groups;
    - Each group gets to use the machines one day per week;
    - All IWCs will be trained to use the machines.

APPENDIX L: INTERVIEW RESPONSES FROM RENT-A-DRUM OSHAKATI

Date: 28 March 2017, 10h00
Interviewers: William Bennett (facilitated), Stefanus Kalangula (asked additional questions related to his project), Emily Chretien (took notes), Sophie Gomarlo (took notes), Peter Hurley (took notes), Robert Kinicki (observed)
Interviewees: David Henok, RAD Oshakati branch supervisor

Current Operations

1. *Can you please tell us about your company and the work that you are involved in?* RAD Oshakati collects as much recyclables as possible in Northern Namibia, sorts and bales the materials, then ships them to Windhoek. The Windhoek RAD branch combines the Oshakati and Windhoek materials and ships them to South Africa for further processing. RAD Oshakati cannot ship directly to South Africa because they do not collect enough materials on their own to fill a truck to efficiently transport them.
2. *What role does your company play in the local waste management and recycling system?* RAD collects as many recyclables as possible in order to keep them out of the dumpsite.
    a) *What towns do you provide service for?*
    RAD Oshakati collects from Oshakati, Ongwediva, Ondangwa, and Okahao.
3. *Where do the materials that you process come from?*
RAD Oshakati collects recyclables from businesses in the area free of charge. Mr. Henok sends employees out in the morning to collect recyclables before town waste collectors bring waste and recyclables to the dumpsites. The company also collects small amounts from IWCs in the nearby dumpsites.
    a) *Who collects these materials for you?*
    RAD has employees who collect from around the city. The company also buys recyclables from IWCs at the dumpsites.
    b) *What is your relationship with these suppliers/collectors?*
    IWCs are not officially employed by RAD, therefore there is not a close relationship. RAD pays the IWCs monthly based on the number of kilograms of each material they collect.
    c) *How much do you pay these suppliers/collectors for each material?*
    Mr. Henok sent the team his complete price list via email following the interview:

Price list - Rent-A-Drum Transport

K4 (Carton Box)		SMX (Paper)		FN (Newspapers)		TetraPack		PET Clear/Caps		Aluminium Cans	
Kg	N$	Kg	N$	Kg	N$	Kg	N$	Kg	N$	Kg	N$
	0.20		0.30		0.10		0.08		0.37		2.5

Glass		Cans/Caps		LDPE Mix (Soft Plastic)		PET Bottles		HDPE Bottles		LLDPE Cling Wrap		Magazines	
Kg	N$	Kg	N$	Kg	N$	Kg	N$	Kg	N$	Kg	N$	Kg	N$
	0.12		0.15		0.27		0.35		0.39		0.21		0.17

Price List - Client Own Transport

K4 (Carton Box)		SMX (Paper)		FN (Newspapers)		TetraPack		PET Clear/Caps		Aluminium Cans	
Kg	N$	Kg	N$	Kg	N$	Kg	N$	Kg	N$	Kg	N$
	0.31		0.35		0.12		0.13		0.39		2.5

Glass		Cans/Caps		LDPE Mix (Soft Plastic)		PET Bottles		HDPE Bottles		LLDPE Cling Wrap		Magazines	
Kg	N$	Kg	N$	Kg	N$	Kg	N$	Kg	N$	Kg	N$	Kg	N$
	0.14		0.18		0.32		0.36		0.42		0.24		0.2

4. *What quantities of recyclables do you collect each month, in weight for each type of material?*
   The monthly volumes RAD collects have been increasing each month.
   a) *About how much of this is purchased from informal waste collectors in dumpsites?*
      RAD does not purchase much from dumpsite IWCs compared to the amounts they collect from businesses and households because IWCs do not collect enough to make it cost-efficient for RAD, it is hard to track each IWC's collection/pay, and Mr. Henok says they are difficult to properly train.
   b) *About how much of this comes from each town?*
      Mr. Henok did not provide a breakdown of collection volumes by town.
5. *What types of recycling processing does your company perform?*
   RAD Oshakati bales materials to make shipping easier. This RAD branch has one baler for plastics and aluminum and one larger baler for cardboard, paper, and steel.
6. *Where do you send your processed materials?*
   RAD Oshakati sends nearly all materials to RAD Windhoek. The company sells PVC to concrete companies, and sells mixed/general waste to companies for energy.
   a) *What further processing is performed there?*
      RAD Windhoek ships the baled materials to South Africa for processing.
   b) *What expenses do you incur from your operations, such as product transportation?*
      RAD pays for the transportation to Windhoek.
7. *What improvements to the local recycling system would benefit your company?*
   Mr. Henok would like to increase collection as much as possible.
8. *Have there been any attempts to improve the recycling system within your company?*
   Mr. Henok has stopped sending waste mixed in with recyclables to the landfill. Instead,

RAD sells it to manufacturing companies that burn it to fuel their machines. Mr. Henok also wants improved training to teach collectors how to sort properly so materials can be collected more efficiently. Mr. Henok sees Oshakati dumpsite collection as the largest potential for growth. He would like to bring a baler to dumpsites so materials there can be collected more efficiently. His idea is to use a small baler that can be transported on a trailer to the dumpsite.

a) *Who initiated these changes?*
   Mr. Henok.
b) *What has worked and what has not?*
   Improved training and the use of a dumpsite baler have not been implemented yet.

Our Study

9. *Do you support the Recycle by Bicycle initiative?*
   Mr. Henok supports the initiative. Last year he assisted the NUST team in piloting the program.
   a) *Why or why not?*
      Mr. Henok supports the Recycle by Bicycle project because the bikes are able to collect from areas where trucks cannot.
10. *What do you foresee as the role of your company if such a local recycling processing system was established in Oshakati?*
    Mr. Henok could not see further processing being implemented in Oshakati, but would like to implement a dumpsite baling system to make RAD's operations more time-efficient. He sees this as a huge potential for RAD and recycling in Oshakati; there are large quantities of material in the dumpsite, but collection is inefficient because IWCs are neither officially employed nor properly trained. Mr. Henok would like RAD to purchase this baling machine, but nothing has been done yet.

Additional Notes/Comments

- RAD Oshakati has 22 total employees.
  - Two employees are at the Ondangwa dumpsite and two are at the Ongwediva dumpsite.
  - Training required for his employees is simple.
- The amount of recyclables RAD Oshakati collects is constantly increasing each month: "We collect very fast."

APPENDIX M: INTERVIEW RESPONSES FROM WILCO ONDANGWA

Date: 29 March 2017, 10h00
Interviewers: Sophie Gomarlo (facilitated), Clarence Ntesa (facilitated), Stefanus Kalangula (asked additional questions related to his project), William Bennett (took notes), Emily Chretien (took notes), Peter Hurley (took notes), Robert Kinicki (observed)
Interviewees: Willem Coetzee, Wilco Recycling Company Owner

Current Operations

1. *Can you please tell us about your company and the work that you are involved in?*
   This branch of Wilco collects recyclables from households, business, and dumpsites mainly in Ondangwa, Oshakati, Ongwediva, and Oshikango. At the Wilco facility, employees sort and bale the materials.
2. *What role does your company play in the local waste management and recycling system?*
   Wilco collects recyclables, sorts, and bales them.
   a) *What towns do you provide service for?*
      Wilco collects from mainly Ondangwa, Oshakati, Ongwediva, and Oshikango.
3. *Where do the materials that you process come from?*
   Wilco collects recyclables from businesses in the area free of charge and from households. Wilco also purchases recyclables from IWCs in the nearby dumpsites.
   a) *Who collects these materials for you?*
      IWCs collect recyclables from the dumpsites and sell them to Wilco. Wilco employees sort material and operate the baler.
   b) *What is your relationship with them?*
      Wilco simply purchases the material from the IWCs and pays the IWCs based on weight of the material they have collected. Wilco has no employees operating in the dumpsites.
   c) *How much do you pay these suppliers/collectors for each material?*
      Mr. Coetzee agreed to sens the team his complete price list via email following the interview. The team exchanged multiple emails with Mr. Coetzee to obtain and confirm the following prices:

      - Prices Wilco pays IWCs at the dumpsite per kilogram for each material:
        - Glass: N$1.70/kg
        - Aluminum Cans: N$5.00/kg
        - Food Cans: N$0.30/kg
        - Steel Cans: N$0.30/kg
        - Mixed Plastics: N$0.80/kg
        - PET Plastic: N$0.80/kg
        - LDPE Plastic: N$0.80/kg
        - HDPE Plastics: N$0.80/kg

- Prices South African processing companies pay Wilco per kilogram for each baled material:
    - Glass: N$0.92/kg
    - Aluminum Cans: N$13.00/kg
    - Food Cans: N$1.00/kg
    - Steel Cans: N$1.00/kg
    - Mixed Plastics: N$3.00/kg
    - PET Plastic: N$3.50/kg
    - LDPE Plastic: N$2.20/kg
    - HDPE Plastics: N$3.00/kg
    - Cardboard Box: N$2.20/kg

4. *What quantities of recyclables do you collect each month, in weight for each type of material?*
   Wilco processes different amounts of material each month. Mr. Coetzee estimated they process about 7 tons of tin in one month, but emphasized that the numbers change every month. The Ondangwa Wilco yard typically produces one truck, or 80 bales, per week.
    a) *About how much of this is purchased from informal waste collectors in dumpsites?*
       The dumpsites produce approximately 10 tons of plastic per month.
    b) *About how much of this comes from each town?*
       Most material that this Wilco branch collects comes from Oshakati.
5. *What types of recycling processing does your company perform?*
   Wilco only bales the materials. There are no other processing techniques used by this Wilco branch. Wilco has a baler at the Wilco yard that can also be transported on a trailer.
6. *Where do you send your processed materials?*
   Wilco sells all materials to companies in South Africa.
    a) *What further processing is performed there?*
       Wilco sells each type of material to a different company. For example, Wilco sells glasses to Consol Glass.
    b) *What expenses do you incur from your operations, such as product transportation?*
       Wilco must pay for the costs of transporting the materials to South Africa, approximately N$19,000 per truckload. When transporting materials to South Africa, Wilco hires a truck that is already making a round trip to South Africa to bring imported goods to Oshana. This is more efficient and saves money. Wilco also has to pay for the high cost of operation, including fuel for the generator that powers the baler.

7. *What improvements to the local recycling system would benefit your company?*
   Mr. Coetzee did not offer any ideas.
8. *Have there been any attempts to improve the recycling system within your company?*
   Mr. Coetzee recently hired 10 to 15 more employees to increase productivity.
   a) *Who initiated these changes?*
      Mr. Coetzee.
   b) *What has worked and what has not?*
      Mr. Coetzee did not comment on the success of this change.

Our Study

9. *Do you support the Recycle by Bicycle initiative?*
   Yes, Mr. Coetzee supports the initiative and would be willing to purchase materials from IWCs using the bicycles.
10. *What do you foresee as the role of your company if such a local recycling processing system was established in Oshakati?*
   Mr. Coetzee supports the idea of processing locally, and would be willing to purchase processed materials.

Additional Notes/Comments

- Wilco's largest cost that Mr. Coetzee is trying to reduce is transportation.
- Both of Wilco's balers are mobile.
- Wilco's generator costs ~N$90,000, and the larger baler costs ~N$140,000.
- Aluminum earns Wilco N$13,000 per ton.

APPENDIX N: DISCUSSION RESPONSES FROM OSHAKATI TOWN COUNCIL MEETING

Date: 30 March 2017, 11h00
Interviewers: Clarence Ntesa (facilitated), Lameck Mwewa (facilitated), William Bennett (presented and took notes), Emily Chretien (presented and took notes), Peter Hurley (presented and took notes), Sophie Gomarlo (presented and took notes), Stefanus Kalangula (presented and took notes)
Participants: 11 Oshakati Town officials (anonymous)

Discussion Questions

1. *Would you support this initiative? [This question refers to this project and the topics discussed in the OTC presentation. Refer to Appendix D.1.]*
    - Yes, OTC definitely supports the initiative.
    - It would benefit the town to "turn waste into money."
    - This would help to minimize the waste management problem in Oshakati.
    - This would help the environment: The town wants to keep their Environmental Certification of compliance with the national Environmental Act.
    - OTC wants to encourage at-the-source separation of materials.
    - OTC wants to engage communities and schools in this initiative.
2. *How do you envision such a system to be managed and operated? Who should be involved? What would be the role of the Town Council?*
    - OTC could create a platform for the IWCs and communities to pick up and facilitate.
    - OTC would allow the IWCs and communities to control it.
    - OTC would provide some regulation such as licensing official IWCs and setting boundaries for where each group operates to prevent conflict.
    - OTC is willing to provide training for IWCs.
    - OTC could provide recycling centers and storage facilities.
3. *What organizational structure would you recommend? (Ex. Contract, corporative, cooperative, individual, etc.)*
    - OTC wants this to be a community-based activity.
    - Each informal settlement could form an IWC group that would collect in their area and jumpstart the project locally.
    - The people would volunteer and organize themselves. They could form associations/unions to give them strength in numbers.
4. *Overall, what are some of the key considerations to ensure a successful system?*
    - It needs to be economically sustainable.
    - These machines/technologies need to be able to be built and maintained locally by the people. They must be inexpensive and easy to maintain.

- Want rain covers/storage facilities to protect equipment and products from weather and crime – these could be provided by OTC.
- Need to find examples of similar initiatives that were successful in other communities. The town can adapt these examples to the local conditions.
- This is turning waste into money: need to have regulations to minimize conflicts.
- Public awareness is key. The initative should include businesses, schools, and informal settlements.
- This initiative starts with the education system, specifically with children.

Additional Comments/Questions from the OTC

- Are the IWCs willing to do this?
- Currently there is no agreement between OTC and RAD or Wilco: "They are stealing our economy."
- OTC is moving forward with plans to completely change the local disposal site: this may affect how the project can be implemented.

APPENDIX O: PHONE CONVERSATION WITH NORTH WEST PLASTIC MANUFACTURERS REPRESENTATIVE

1. *What materials does your company use for your plastics manufacturing?*
   North West Plastic Manufacturers manufactures water tanks and HDPE pipes. The company uses a mixture of HDPE and LDPE to manfucature the pipes.
   a) *Do you use any recycled materials in your manufacturing? If so, what percentage of your materials are recycled?*
      The company only uses virgin plastics to manufacture water tanks, and HDPE and LDPE to manufacture pipes.
   b) *In what form do you purchase these materials? (Examples: chipped plastic, plastic pellets, baled plastics.)*
      North West Plastic Manufacturers purchases recycled plastic pellets.
   c) *From whom do you purchase these materials? How are they transported from the supplier to the manufacturing location?*
      The company purchases the pellets from suppliers in South Africa. The representative did not name specific companies.
   d) *How much do you pay for these materials?*
      North West Plastic Manufacturers pays N$11 per kilogram for recycled pellets.
   e) *What volume of material do you purchase?*
      The volume the company purchases varies depending on the production rate each month. Volumes range from 33 to 66 tons per month.
   f) *How do you ensure the quality of the material that you purchase?*
      The company tests the materials in a laboratory to ensure it meets quality standards for mechanical properties, including strength and durability.
2. *Assuming the supply to be constant and sufficient, would your company be interested in purchasing locally supplied recycled materials for your manufacturing? Why or why not?*
   Yes, the representative believes North West Plastics Manufacturers may be interested, as long as the material meets the quality standards.
   a) *What requirements (material form, quality, volume, price) would this supplier need to meet in order for you to consider purchasing from them?*
      The representative emphasized that the materials would need to be clean and meet their quality standards. Additionally, the company only purchases plastic in the form of pellets.
   b) *How could a small-scale recycling processing system in Oshakati could benefit your company?*
      The representative repeated that they only purchase high-quality pelletized plastics, and that other companies perform the recycling processes. He referred the team to Plastic Packaging Polymer Recyclers for more information on plastic recycling and pelletizing.

APPENDIX P: PRICE QUOTE AND SPECIFICATIONS FOR A MOCO SHREDDING MACHINE AZ 09F

MOCO Maschinen- und Apparatebau GmbH u. Co. KG

Großer Stellweg 19 D - 68519 Viernheim Tel.: +49 (0)6204 / 9685-0 Fax: +49 (0) 6204 - 9685-55
E-Mail: moco-shredder@t-online.de Internet: http//www.moco-shredder.de

MOCO Maschinen- und Apparatebau - Großer Stellweg 19 - D-68519 Viernheim

WORCESTER POLYTECHNIC INSTITUTE
Mr. Peter Hurley
100 Institute Road
01609-2280 Worcester, MA
USA

Deutsche Bank PGK AG
BLZ: 670 700 24 Konto Nr.: 5429 246
IBAN: DE22 6707 0024 0542 9246 00
SWIFT (BIC): DEUTDEDBMAN

USt-ID. DE 192003412

Offer No.	**PL 57350**	Date 19.04.2017	Your inquiry mail from Apr 13, 2017 / Project Northern Namibia
	In charge:	Karl Görtz	

Dear Mr. Hurley,

Thank you for your inquiry and the given details. We submit following offer according to our general conditions of sale and delivery:

Offer-Pos. 1

1 MOCO Feeder Type ZB 01

Application:

Drive:	Parallel shaft geared motor 0.55 kW, 1450 : 4 rpm, direct start, mounting position H 3
Power supply:	400/690 V - 50 Hz
Type of protection:	IP 55, Insulation-class F

Consisting essentially of:

Reinforced 8 respectively 10 mm sheet steel weldment with ball bearing feeding rotor and flanged geared motor.

Charging aperture: 830 x 500 mm

Amount/position **11.040,00 €**

Offer-Pos. 2

1 MOCO Shredding Machine AZ 09F

Application:	Plastic and Aluminium cans 20 mm wide pcs and strips / approx. 150 kg/h
Drive:	Parallel shaft geared motor 7.5 kW, 1450 : 34 rpm, direct start, mounting position H 3
Power supply:	400/690 V - 50 Hz
Type of protection:	IP 55, Insulation-class F
Cutting chamber:	435 x 500 mm
Cutter arrangement:	19 mm wide, single spaced

Consisting essentially of:

Page 1 of 2

The goods remain property of MOCO until complete payment is done. Valid are our sales and delivery conditions. Legal domicile for delivery and payment is agreed as Lampertheim. District court Darmstadt, registered under Lampertheim HRA 61766, Managing Director Karl Goertz.

MOCO Maschinen- und Apparatebau GmbH u. Co. KG

Offer No. PL 57350

MOCO-gearbox and cage in heavy steel weldment, annealed for releasing stresses, bearing sides with wear plates, oil quenched reduction gear, two counter-rotating hexagonal shafts with pushed on cutting discs of hardened special steel, individually exchangeable.

Two rakes made of segments braced by dovetailed fixing plates.

Amount/position **23.225,00 €**

Offer-Pos. 3

		Pr.p.u.	Total
1	**Frame for 1.1 cbm MGB** Welded construction made of U-beams and rectangular tubes with limit switch safety flap (start release by container) according drawing no.: ZB1/53-4 Floor space: 1620 x 1340 mm Height: 1380 mm	2.340,00 €	2.340,00 €
1	**Control panel** Electric control panel (according to VDE/CE-safety prescriptions). With PLC (Moeller Electric) and all necessary control elements, automatic, overload dependent reverse control, protective motor switch, transformer and automatic stop after three short-time reversing. Supply Voltage: 400 V - 50 Hz Control Voltage: 230 V - 50 Hz, 24 V DC Type of protection: IP 55	2.560,00 €	2.560,00 €

Amount/position **4.900,00 €**

Total amount **39.165,00 €**

Delivery time: approx. 8-10 weeks after final order clarification.

Delivery terms: ex works

Terms of payment: 30 % deposit with order confirmation, 70 % after successful FAT but before delivery

Price validity: 6 months.

We do hope that our quotation meets your requirements. Please don't hesitate to contact us in case of further questions.

Sincerely yours
MOCO GmbH & Co. KG

Karl Görtz

Page 2 of 2

The goods remain property of MOCO until complete payment is done. Valid are our sales and delivery conditions. Legal domicile for delivery and payment is agreed as Lampertheim. District court Darmstadt, registered under Lampertheim HRA 61766, Managing Director Karl Goertz.

APPENDIX Q: PRICE QUOTE AND SPECIFCATIONS FOR A 13 KVA STANDBY FAW GENERATOR

RAND PRICES AT 01 APRIL 2017

SILENT DIESEL GENERATOR SETS

Phone Int: +2711-312-4673
Phone Alt: +2710-597-7788
E-Mail: sales@genking.co.za
Website: www.genking.co.za

MODEL	PRIME kVA	STANDBY kVA	PHASE	DESCRIPTION	ATS INCLUDED	UNIT PRICE	TRANSPORT PRICE CFR WINDHOEK	TOTAL PRICE EX VAT WINDHOEK
Outback 1500 RPM Range (All Outback sets include Silent Canopies)								
GKOS-13	12	13,2	1	Standby Silent FAW 1 Phase	Included	R 77 900	R 4 800	R 82 700
GKOS-22	20	22	1	Standby Silent FAW 1 Phase	Included	R 78 900	R 4 800	R 83 700
GKOS-22 SS	20	22	1	Standby Super Silent FAW 1 Phase	Included	R 83 900	R 4 800	R 88 700
GKO3-16	15	16,5	3	Standby Silent FAW 3 Phase	Included	R 72 900	R 4 800	R 77 700
GKO3-25	23	25	3	Standby Silent FAW 3 Phase	Included	R 73 900	R 4 800	R 78 700
GKO3-25 SS	23	25	3	Standby Super Silent FAW 3 Phase	Included	R 79 900	R 4 800	R 84 700
GKO3-40	37	40	3	Standby Silent FAW 3 Phase	Included	R 99 900	R 5 500	R 105 400
GKO3-55	50	55	3	Standby Silent FAW 3 Phase	Included	R 108 900	R 5 500	R 114 400
All sets include Silent Canopies								
GKL-50	46	50	3	Standby Silent Lovol 3 Phase	Included	R 112 900	R 5 500	R 118 400
GKC-46	42	46	3	Standby Silent Cummins 3 Phase	Included	R 139 900	R 5 500	R 145 400
GKC-68	62,5	68	3	Standby Silent Cummins 3 Phase	Included	R 149 900	R 5 500	R 155 400
GKL-80	74	80	3	Standby Silent Lovol 3 Phase	Included	R 154 900	R 7 500	R 162 400
GKL-110	100	110	3	Standby Silent Lovol 3 Phase	Included	R 169 900	R 7 500	R 177 400
GKC-110	100	110	3	Standby Silent Cummins 3 Phase	Included	R 184 900	R 7 500	R 192 400
GKL-150	132	145	3	Standby Silent Lovol 3 Phase	Included	R 194 900	R 7 500	R 202 400
GKC-150	132	145	3	Standby Silent Cummins 3 Phase	Included	R 219 900	R 7 500	R 227 400
GKL-200	180	200	3	Standby Silent Lovol 3 Phase	Included	R 274 900	R 8 250	R 283 150
GKV-220	200	220	3	Standby Silent Volvo 3 Phase	Included	R 329 900	R 16 000	R 345 900
GKV-265	250	265	3	Standby Silent Volvo 3 Phase	Included	R 359 900	R 16 000	R 375 900
GKV-330	300	330	3	Standby Silent Volvo 3 Phase	Included	R 399 900	R 16 000	R 415 900
GKV-385	350	385	3	Standby Silent Volvo 3 Phase	Included	R 449 900	R 16 000	R 465 900
GKS-440	400	440	3	Standby Silent Scania 3 Phase	Included	R 499 900	R 22 000	R 521 900
GKV-500	450	500	3	Standby Silent Volvo 3 Phase	Included	R 589 900	R 23 100	R 613 000
GKV-550	500	550	3	Standby Silent Volvo 3 Phase	Included	R 619 900	R 25 300	R 645 200
GKS-610	550	610	3	Standby Silent Scania 3 Phase	Included	R 649 900	R 28 300	R 678 200
GKV-700	630	700	3	Standby Silent Volvo 3 Phase	Included	R 799 900	R 28 300	R 828 200
GKM-880	800	880	3	Standby Silent Mitsubishi 3 Phase	Included	R 1 299 900	R 28 300	R 1 328 200
Extra's								
GKC-WHS	Block Water Heater other units							R 5 200
GKC-WHS	Block Water Heater Scania							R 5 200
GKC-WHS	Block Water Heater Volvo							R 7 900
GKC-GSM	GSM Modem for Cell Phone Notification (Available for Cummins, Volvo and Scania sets only)							R 6 900
** Generator Trailers on sizes up to GKC-150 can be quoted on request								

ENGINE SPECIFICATIONS

• All ratings are quoted at maximum ratings at sea level and de rating will be applicable at altitude

Diesel Generator Model	4DW81-23D
Engine Make	FAW
Displacement	2,27L
Cylinder bore / Stroke mm	85mm x 100mm
Fuel system	In line fuel injection Pump
Cylinders	4
Cylinder Arrangement	Vertical In-Line
Engine Output Power at 1500 RPM (kW)	17
Turbo or Normally Aspirated	Normally Aspirated
Cycle	4 Stroke
Combustion system	Direct Injection
Compression ratio	17:1
Direction of rotation	Clockwise viewed from fan
Fuel Tank Capacity	180L
Fuel Consumption 100%	4.85 L/H
Fuel Consumption 75%	3.64 L/H
Fuel Consumption 50%	2.42 L/H
Fuel Consumption 25%	1.21 L/H
Oil Type	15W40
Oil Capacity	7.8 L
Cooling Method	Radiator water-cooled
Coolant capacity (engine only)	12.5 L
Starter	12V DC
Starting System and Governor	Electronic
Engine Speed	1500 rpm

ALTERNATOR SPECIFICATIONS

Standby Power Output (kVA)	13.2
Prime Power Output (kVA)	12
Insulation Class	H
Type	Brushless
Phase and Connection	Single phase, 4 wire
AVR	YES
AVR Model	SX460
Voltage Regulation	± 1%
Voltage	230 volts
Rated Frequency	50HZ
Voltage Regulate Change	≤ ±10% UN
Phase change rate	± 1%
Power Factor	1
Protection Class	IP22
Stator	2 / 3 pitch
Rotor	Single Bearing

APPENDIX R: PRICE QUOTE AND SPECIFICATIONS FOR A SOLAR AGE SHS4 SOLAR PANEL

SOLAR AGE NAMIBIA (PTY) LTD

Solar Age Namibia (Pty) Ltd
2 Jeppe Stree, Northern Industrial Area
P O Box 9987, Windhoek, Namibia
Tel.:+264 – 61 – 215 809
Fax.: +264 – 61 – 215 793
Email: info@solarage.com
Web: www.solarage.com

SOLAR HOME SYSTEMS STANDARD KITS

Budgetary Prices

SOLAR HOME SYSTEM	DESCRIPTION (WHAT WILL WORK THERE)	PRICE (VAT INCL.)
SHS 1	10 x Lights, 1 x Radio and Cellphones Charging	N$ 15 883.84
SHS 2	10 x Lights, 1 x Radio, 1 x Color TV and Cellphones Charging	N$ 25 008.17
SHS 3	10 x Lights, 1 x Radio, 1 x Color TV, 1 x Microwave and Cellphones Charging	N$ 44 465.44
SHS 4	10 x Lights, 1 x Radio, 1 x Color TV, 1 x Fridge/Freezer and Cellphones Charging	N$ 60 043.58
SHS 5	10 x Lights, 1 x Radio, 1 x Color TV, 1 x Fridge/Freezer, 1 x Microwave, 1 x Aircon and Cellphones Charging	N$ 191 707.86
SHS 6	10 x Lights, 1 x Jukebox and Cellphones Charging	N$ 38 760.98
SHS 7	10 x Lights, 1 x Jukebox, 1 x Jackpot and Cellphones Charging	N$ 55 964.15
SHS 8	10 x Lights, 1 x Jukebox, 1 x Jackpot, 1 x Fridge/Freezer and Cellphones Charging	N$ 69 914.48

PLEASE NOTE: INSTALLATION AND/OR TRANSPORT IS NOT INCLUDED IN ANY OF THESE PRICES

(AVAILABLE ON REQUEST)

Solar Age Namibia – Photovoltaic Specialists (Since 1989)

Solar Age Namibia
2 Jeppe Street
Northern Industrial Area
P.O. Box 9987
Windhoek Namibia
Tel: +264- 61- 215809
Fax: +264- 61- 215793
info@solarage.com
www.solarage.com

Energy Supply Sheet

1 Available Budget

Solar System:	
1.1 Inverter	kW
1.2 Battery	Ah
1.3 System Voltage	V
1.4 Solar array	kW
Generator:	
1.5 Make	
1.6 Model	
1.7 Size	kW
1.8 Single/ Three Phase	

3 General Information

3.1 System Type	Residential	
	Farm	
	Lodge	
	Commercial	

3.2 Reason	Prevent Power Outages	
	NamPower Independency	
	Reducing Electricity Bill	
	No electricity available	

3.3 PV Tracker Required	Yes	No
3.4 220V Battery Charging required	Yes	No
3.5 Required Generator runtime		Hours
3.6 Required System Autonomy		Days
3.7 Installation required	Yes	No

4 Personal Information

Name	
Farm/Place	
Address	
Phone N°	
Fax N°	
E-Mail	
Date	

5 Type of load	6 Power (W)	7 Qty	8 Daily use (hrs)	9 Days per week	10 Daily Energy (Wh/d)
Ceiling Lights	7				
Lights CFL	7				
Lights CFL	11				
Lights CFL	15				
Lights CFL	20				
Lights CFL	36				
Colour TV 54 cm	90				
Colour TV 72 cm	140				
Plasma TV 105cm Flatscreen	180				
Video / DVD	30				
Decoder	30				
V.Sat (Telephone)	25				
HiFi	20				
Fax	10				
Computer/Laptop	40				
Computer/Desktop	150				
Printer	20				
Fridge 300 litre (<1.5kWh/day)	120				
Freezer 300 litre (<1.5kWh/day)	150				
Fridge/Freezer comb. (<1.5kWh/day)	180				
DC Freezer 165 litre (<0.782kWh/day)	90				
DC Freezer 225 litre (<0.908kWh/day)	90				
Kitchen appliances	400				
Microwave	600				
Vacuum Cleaner	1.200				
Hairdryer	900				
Sewing machine	80				
Washing- machine/cold	500				
Juke Box	200				
Gambling machine	150				
Ceiling fan	70				
Workshop tool	800				
Swimming pool pump	750				
Alarm System	10				
Other					

Please do not hesitate to contact us for further information

APPENDIX S: COST-BENEFIT ANALYSIS RESULTS FOR POTENTIAL PROCESSES

S.1 Industrial Shredder – Generator-Powered, Processing Plastic

Plastic

German MOCO Shredding Machine AZ 09F

Namibian 13kva Standby FAW Generator *Fiscal Year*

Costs	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Initial Machine Cost	$330,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$330,000.00
Initial Generator Cost	$77,900.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$77,900.00
Maintanance Cost	$6,017.23	$14,935.97	$22,519.30	$29,490.78	$36,065.80	$42,350.95	$48,409.54	$54,283.31	$60,001.74	$65,586.68	$71,054.90	$450,716.19
Fuel Cost	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$1,028,808.00
Total	$507,445.23	$108,463.97	$116,047.30	$123,018.78	$129,593.80	$135,878.95	$141,937.54	$147,811.31	$153,529.74	$159,114.68	$164,582.90	$1,887,424.19

Benefits	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Profit	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$6,101,867.20
Total	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$6,101,867.20

Analysis	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Cost-Benefit Ratio	1.09	5.11	4.78	4.51	4.28	4.08	3.91	3.75	3.61	3.49	3.37	3.23

Per Person Analysis	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Average
Profit per IWC	$1,575.67	$14,875.04	$14,622.26	$14,389.88	$14,170.71	$13,961.21	$13,759.26	$13,563.46	$13,372.85	$13,186.68	$13,004.41	$12,771.04
Profit per month per IWC	$131.31	$1,239.59	$1,218.52	$1,199.16	$1,180.89	$1,163.43	$1,146.60	$1,130.29	$1,114.40	$1,098.89	$1,083.70	$1,064.25

S.2 Industrial Shredder – Generator-Powered, Processing Aluminum

Aluminum

German MOCO Shredding Machine AZ 09F

Namibian 13kva Standby FAW Generator *Fiscal Year*

Costs	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Initial Machine Cost	$330,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$330,000.00
Initial Generator Cost	$77,900.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$77,900.00
Maintanance Cost	$6,017.23	$14,935.97	$22,519.30	$29,490.78	$36,065.80	$42,350.95	$48,409.54	$54,283.31	$60,001.74	$65,586.68	$71,054.90	$450,716.19
Fuel Cost	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$1,028,808.00
Total	$507,445.23	$108,463.97	$116,047.30	$123,018.78	$129,593.80	$135,878.95	$141,937.54	$147,811.31	$153,529.74	$159,114.68	$164,582.90	$1,887,424.19

Benefits	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Profit	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$2,862,860.00
Total	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$2,862,860.00

Analysis	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Cost-Benefit Ratio	0.51	2.40	2.24	2.12	2.01	1.92	1.83	1.76	1.70	1.64	1.58	1.52

Per Person Analysis	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Average
Profit per IWC	$8,239.51	$5,059.87	$4,807.09	$4,574.71	$4,355.54	$4,146.03	$3,944.08	$3,748.29	$3,557.68	$3,371.51	$3,189.24	$2,955.87
Profit per month per IWC	$686.63	$421.66	$400.59	$381.23	$362.96	$345.50	$328.67	$312.36	$296.47	$280.96	$265.77	$246.32

S.3 Industrial Shredder – Generator-Powered, Processing Plastic & Aluminum

Plastic & Aluminum

German MOCO Shredding Machine AZ 09F

Namibian 13kva Standby FAW Generator

Fiscal Year

Costs	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Initial Machine Cost	$330,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$330,000.00
Initial Generator Cost	$77,900.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$77,900.00
Maintanance Cost	$6,017.23	$14,935.97	$22,519.30	$29,490.78	$36,065.80	$42,350.95	$48,409.54	$54,283.31	$60,001.74	$65,586.68	$136,641.57	$516,302.87
Fuel Cost	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$93,528.00	$1,028,808.00
Total	$507,445.23	$108,463.97	$116,047.30	$123,018.78	$129,593.80	$135,878.95	$141,937.54	$147,811.31	$153,529.74	$159,114.68	$230,169.57	$1,953,010.87

Benefits	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Profit	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$8,964,727.20
Total	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$8,964,727.20

Analysis	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Cost-Benefit Ratio	1.61	7.51	7.02	6.62	6.29	6.00	5.74	5.51	5.31	5.12	3.54	4.59

Per Person Analysis	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Average
Profit per IWC	$10,251.00	$23,550.37	$23,297.60	$23,065.21	$22,846.05	$22,636.54	$22,434.59	$22,238.80	$22,048.18	$21,862.02	$19,493.52	$21,247.63
Profit per month per IWC	$854.25	$1,962.53	$1,941.47	$1,922.10	$1,903.84	$1,886.38	$1,869.55	$1,853.23	$1,837.35	$1,821.83	$1,624.46	$1,770.64

S.4 Industrial Shredder – Solar-Powered, Processing Plastic

Plastic

German MOCO Shredding Machine AZ 09F

Solar Age Namibia SHS4 Solar Panel

Fiscal Year

Costs	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Initial Machine Cost	$330,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$330,000.00
Initial Solar Panel Cost	$60,043.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$60,043.00
Maintanance Cost	$5,753.80	$14,282.11	$21,533.45	$28,199.73	$34,486.92	$40,496.91	$46,290.27	$51,906.90	$57,375.00	$62,715.43	$67,944.26	$430,984.79
Total	$395,796.80	$14,282.11	$21,533.45	$28,199.73	$34,486.92	$40,496.91	$46,290.27	$51,906.90	$57,375.00	$62,715.43	$67,944.26	$821,027.79

Benefits	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Profit	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$6,101,867.20
Total	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$554,715.20	$6,101,867.20

Analysis	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Cost-Benefit Ratio	1.40	38.84	25.76	19.67	16.08	13.70	11.98	10.69	9.67	8.84	8.16	7.43

Per Person Analysis	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Average
Profit per IWC	$5,297.28	$18,014.44	$17,772.72	$17,550.52	$17,340.94	$17,140.61	$16,947.50	$16,760.28	$16,578.01	$16,399.99	$16,225.70	$16,002.54
Profit per month per IWC	$441.44	$1,501.20	$1,481.06	$1,462.54	$1,445.08	$1,428.38	$1,412.29	$1,396.69	$1,381.50	$1,366.67	$1,352.14	$1,333.55

S.5 Industrial Shredder – Solar-Powered, Processing Aluminum

Aluminum

German MOCO Shredding Machine AZ 09F

Solar Age Namibia SHS4 Solar Panel

Fiscal Year

Costs	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Initial Machine Cost	$330,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$330,000.00
Initial Solar Panel Cost	$60,043.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$60,043.00
Maintanance Cost	$5,753.80	$14,282.11	$21,533.45	$28,199.73	$34,486.92	$40,496.91	$46,290.27	$51,906.90	$57,375.00	$62,715.43	$67,944.26	$430,984.79
Total	$395,796.80	$14,282.11	$21,533.45	$28,199.73	$34,486.92	$40,496.91	$46,290.27	$51,906.90	$57,375.00	$62,715.43	$67,944.26	$821,027.79

Benefits	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Profit	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$2,862,860.00
Total	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$260,260.00	$2,862,860.00

Analysis	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Cost-Benefit Ratio	0.66	18.22	12.09	9.23	7.55	6.43	5.62	5.01	4.54	4.15	3.83	3.49

Per Person Analysis	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Average
Profit per IWC	$4,517.89	$8,199.26	$7,957.55	$7,735.34	$7,525.77	$7,325.44	$7,132.32	$6,945.10	$6,762.83	$6,584.82	$6,410.52	$6,187.37
Profit per month per IWC	$376.49	$683.27	$663.13	$644.61	$627.15	$610.45	$594.36	$578.76	$563.57	$548.73	$534.21	$515.61

S.6 Industrial Shredder – Solar-Powered, Processing Plastic & Aluminum

Plastic & Aluminum

German MOCO Shredding Machine AZ 09F												
Solar Age Namibia SHS4 Solar Panel	*Fiscal Year*											
Costs	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
Initial Machine Cost	$330,000.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$330,000.00
Initial Solar Panel Cost	$60,043.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$60,043.00
Maintanance Cost	$5,753.80	$14,282.11	$21,533.45	$28,199.73	$34,486.92	$40,496.91	$46,290.27	$51,906.90	$57,375.00	$62,715.43	$67,944.26	$430,984.79
Total	$395,796.80	$14,282.11	$21,533.45	$28,199.73	$34,486.92	$40,496.91	$46,290.27	$51,906.90	$57,375.00	$62,715.43	$67,944.26	$821,027.79

Benefits	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
Profit	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$8,964,727.20
Total	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$814,975.20	$8,964,727.20

Analysis	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
Cost-Benefit Ratio	2.06	57.06	37.85	28.90	23.63	20.12	17.61	15.70	14.20	12.99	11.99	10.92

Per Person Analysis	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Average**
Profit per IWC	$13,972.61	$26,689.77	$26,448.06	$26,225.85	$26,016.28	$25,815.94	$25,622.83	$25,435.61	$25,253.34	$25,075.33	$24,901.03	$24,677.88
Profit per month per IWC	$1,164.38	$2,224.15	$2,204.00	$2,185.49	$2,168.02	$2,151.33	$2,135.24	$2,119.63	$2,104.45	$2,089.61	$2,075.09	$2,056.49

S.7 Bicycle Shredder – Manual-Powered, Processing Plastic

Plastic

Bicycle Shredder	*Fiscal Year*											
Costs	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
Initial Machine Cost	$6,692.50	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$6,692.50
Maintanance Cost	$98.73	$245.06	$369.48	$483.86	$591.74	$694.86	$794.27	$890.64	$984.46	$1,076.09	$1,165.81	$7,394.99
Total	$6,791.23	$245.06	$369.48	$483.86	$591.74	$694.86	$794.27	$890.64	$984.46	$1,076.09	$1,165.81	$14,087.49

Benefits	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
Profit	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$112,038.06
Total	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$10,185.28	$112,038.06

Analysis	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
Cost-Benefit Ratio	1.50	41.56	27.57	21.05	17.21	14.66	12.82	11.44	10.35	9.47	8.74	7.95

Per Person Analysis	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Average**
Profit per IWC	$113.14	$331.34	$327.19	$323.38	$319.78	$316.35	$313.03	$309.82	$306.69	$303.64	$300.65	$296.82
Profit per month per IWC	$9.43	$27.61	$27.27	$26.95	$26.65	$26.36	$26.09	$25.82	$25.56	$25.30	$25.05	$24.73