A Proposed Recycling Facility for the Informal Waste Collectors of Oshakati

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ABBREVIATIONS AND NOTATIONS

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

WPI: Worcester Polytechnic Institute

CHAPTER 1: INTRODUCTION

Oshakati is a large town in northern Namibia that has become a major international trade center for the country. Both Oshakati's economy and population are developing at a steady rate (Namibia Statistics Agency, 2012b). However, the town's waste management system has not kept pace with this growth. This uneven development has led to an abundance of waste in the local dumpsite. Additionally, wealth in Namibia is unevenly distributed, resulting in a national unemployment rate of 28.1% (Central Intelligence Agency, 2014). Throughout Namibia, some unemployed individuals collect recyclable materials from dumpsites and sell them to private recycling companies to generate a small income for their families. These workers are known as informal waste collectors (IWCs).

Approximately 30 IWCs work in the Oshakati dumpsite daily, which exposes them to dangerous pathogens and toxic chemicals. These workers are making an average of just N$190 (US$14.50) per month for their efforts (Haukena, 2017). This represents just 2.8% of the average Namibian monthly salary of N$6,802 (US$519.12), placing IWCs below the national food poverty line of N$204.05 monthly wages. This project will explore strategies to improve Oshakati's informal recycling system and create a sustainable livelihood for IWCs.

Namibia University of Science and Technology (NUST) has already sponsored several projects that attempted to improve the waste management system and working conditions for IWCs in Namibia. The latest of these projects were the Recycle by Bicycle project series, which NUST conducted in Windhoek, Walvis Bay, Swakopmund, Ongwediva, and Oshakati. These projects studied potential waste collection strategies that will take IWCs out of the dumpsites and help them collect more recyclables directly from households to improve their collection rates and earnings. The project prototype consists of a bicycle with an attached trailer. IWCs can ride this bicycle from household to household and collect 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 landfill environment.

The Recycle by Bicycle study in Oshakati showed that the bicycle initiative could increase the income of IWCs in Oshakati by N$0.75 per hour, a 71% increase to their current earnings (Haukena, 2017). However, this still leaves IWCs below the national poverty line. Despite the improved collection methods, IWC earnings are still low primarily because of the low sale prices for recyclable materials set by the private recycling companies in the region. These private recycling companies, such as Rent-a-Drum (RAD) and Wilco, package the collected materials and ship them to processing plants in South Africa and other foreign countries. Due to the lack of recycling processing facilities in the area, these companies expend large amounts of money on material transportation, thus resulting in decreased wages for IWCs. There is potential to develop a simple processing system in Oshakati that would minimize transportation costs and increase profits for IWCs involved in Oshakati's recycling industry.

This project aims to increase the earnings and livelihoods of informal waste collectors in Oshakati by making recommendations to integrate them into a restructured recycling processing system. WPI students, in collaboration with students and professors at NUST, will consult key stakeholders in the community, particularly IWCs, to gain understanding of the current recycling system and to develop the requirements a local recycling processing structure would need to meet. The team will then consider and analyze multiple processing systems for Oshakati, and ultimately select one process that will best represent the project goals. The final recommendations for Oshakati will include the proposed recycling process, the cost-benefit analysis results, a list of potential customers for the product generated by the plant, and a list of potential investors for the proposed system. This recommended system should be a cost-effective, sustainable closed-loop system that integrates IWCs into a formal recycling processing structure to improve both their incomes and working conditions.

CHAPTER 2: BACKGROUND

Unemployment and inefficient waste management are two challenges that are troubling the country of Namibia and more specifically the town of Oshakati. This chapter begins with a brief discussion of the history and social scene of Oshakati. Section 2.2 explains the local waste management problems 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 then 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 Oshakati's informal waste collectors.

2.1 Introduction to the Region

The Republic of Namibia lies on the southwestern coast of Africa, as shown in Figure 1. 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 of 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 US$4,673.57 (The World Bank, 2017). However, this wealth is not evenly distributed; approximately two-thirds of the total population are left in poverty (Green, 2016). In 2011, the Namibia Statistics Agency (2012b) established the national poverty line at N$377.96 (US$28.79) monthly income for "poor," at N$277.54 (US$21.14) monthly income for the "severely poor," and at N$204.05 (US$15.53) monthly income for the "food poverty line," as shown in Table 1. The more developed cities in Namibia, such as Windhoek, have an established infrastructure that allows for a steady population growth. However, the rest of the country is significantly less developed and still lacks sufficient infrastructure to handle population increases.

Figure 1: Map of Namibia (Encyclopedia Britannica, 1998)

Table 1: National Poverty Lines in Namibia (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 2. The three largest cities in Oshana are Ondangwa, Ongwediva, and Oshakati. Oshakati is the capital of the Oshana Province, and is the largest urban settlement in the region. While modern-day Oshana is home to the most businesses out of all 14 regions of Namibia, the region originally focused on agriculture. The urban expansion of the region offers economic promise, but the development of infrastructure and employment opportunities is not keeping up with the rate of urbanization.

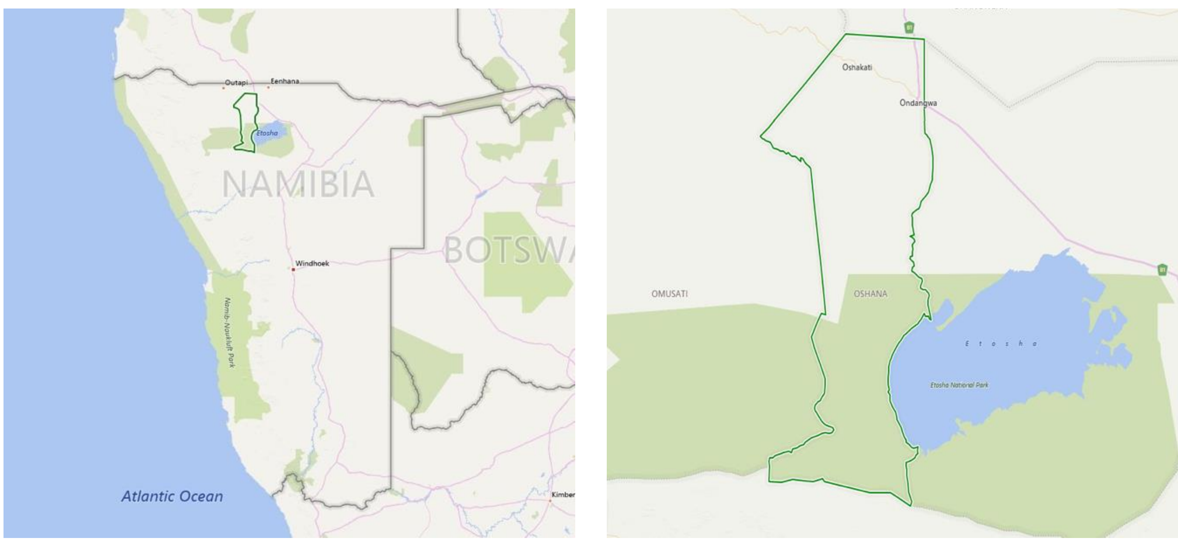

Figure 2: Maps of Oshana Province (Bing Maps, 2017)

2.1.2 Oshakati

Oshakati is the hub of northern Namibia and the fifth largest urban settlement in the country (National Planning Commission, 2011). Located 40 miles south of the Angolan border, Oshakati has developed into a major international trade platform. 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). As one of the only areas of northern Namibia with an established trading system, the people of Oshakati enjoy lively streets and an exciting entertainment scene.

In the years before Namibia's independence, white South African soldiers moved into Oshakati East as a result of 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, which section 2.2.3 describes later. Although Namibia's capital, Windhoek, has an established waste management and recycling system, most towns and communities in Namibia, including Oshakati, do not have adequate waste management regulations or infrastructure (Namibia, 2016).

2.2.1 Waste Collection in Oshakati

The Oshakati Town Council plays a minimal role in the town's current waste collection and management system. Table 2 shows that the town allocated N$4.2 million, or US$324,200, to the solid waste management program during the 2013-2014 fiscal year (Mughal et al., 2014). This equates to approximately N$114 (US$8.80) per capita per year. This is less than one quarter of Windhoek's allocation for solid waste management, which is approximately N$460 (US$35.50) 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$500,000 (Mughal et al., 2013). The Oshakati Town Council dedicates few resources to the formal waste collection and management system, thus the local system lacks sufficient infrastructure and efficiency.

Table 2: Oshakati Town Waste Management Budget (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 does spend on the waste management program (Mughal et al., 2013). 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 once or twice per 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 landfill, pictured in Figure 3. Residents and small, private waste collectors may also drop off waste at the dumpsite.

Figure 3: Oshakati Dumpsite (Mughal, 2014)

The Oshakati landfill covers an area of approximately 62,000 square meters, and is located four kilometers west of the town center, as shown in Figure 4 (Alsins et al., 2013). The dumpsite is quite busy and disorganized with 11 separate town-contracted companies making daily deliveries, in addition to the many individuals dropping off small loads of waste. The landfill employees do not provide much direction or regulation for where to dump the waste. As a result, waste often builds up at the front of the dumpsite near the entrance, blocking access to the rest of the landfill. This requires frequent burning of waste (pictured in Figure 5) to create space for additional trash 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 visitors to the landfill describing the conditions as "bad or very bad," (Mughal et al., 2014).

Figure 4: Location of the Dumpsite Relative to Oshakati, Outlined in Red (Google Maps, 2017)

Figure 5: Burning Waste in the Oshakati Dumpsite (Alsins et al., 2013)

In addition to the disorganized atmosphere caused by deliveries to the landfill, there is also a constant removal of waste from the dumpsite. Approximately 30 individuals operate as informal waste collectors (IWCs) at the Oshakati landfill (Haukena, 2017). These individuals, nearly all women, sort through the waste, collecting recyclable materials to sell to private recycling companies. Figure 6 depicts one such IWC at work in the Oshakati landfill. The Oshakati government has an official register of collectors operating at the town landfill, although not all of the IWCs currently working are registered (Yang & Peuya, 2015). The register 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 (Shigwedha, 2010). Rent-a-Drum (RAD) and Wilco, two private corporations that purchase recyclable materials for processing, employee representatives at the Oshakati landfill to collect recyclables from IWCs. Both companies pay the representatives a set price per kilogram for each type of recyclable material. It is the responsibility of these representatives to disburse monthly payments to their IWC suppliers. An IWC operating at the Oshakati landfill and selling materials to either RAD or Wilco earns an average of N$1.06 (US$0.08) per hour of labor, according to a recent study by Haukena (2017). For an IWC working 8 hours a day, 5 days a week, this amounts to a monthly income of approximately N$190 (US$14.22). This places Oshakati's IWC earnings at 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 47.9% below the national upper bound poverty line, 31.5% below the lower bound poverty line (Namibia Statistics Agency, 2012a). Thus, the Namibian government classifies IWCs operating in the Oshakati landfill as "severely poor" and below the food poverty line.

Figure 6: Informal Waste Collector Working in the Oshakati Dumpsite (Haukena, 2009)

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 overwhelming idea 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 unaware of the benefits related to a proper waste management system and have limited understanding of the environmental and health concerns associated with improper waste disposal. Residents see little value in waste and waste management occupations (Yang & Peuya, 2015). Of those living in informal settlements, 61% have received education through the fourth grade or less (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 how proper waste practices should be executed. 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 in term of this section," (Environmental Management Act, 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 there was no further policy written by the minister to approve sites for disposal. Thereby, the Act had no positive impact on the waste management issue in Oshakati.

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 landfills are very dangerous and compromise IWCs' health. Oshakati burns waste frequently to clear room in the landfill, releasing harmful chemicals and bacterial contaminants into the air and soil. IWCs' skins and lungs are exposed to high levels of these toxins as they work in the landfill. Laws require IWCs to wear protective clothing and equipment while working in the landfill, but this law is often broken and rarely enforced, which can result in injury or infection (Shigwedha, 2010). The job is also belittling and looked down upon by society, which affects the psychological well-being of IWCs. Performing labor-intensive work for such low pay can 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 landfills while also recovering monetary value from waste materials (Hasheela, 2009). Figure 7 depicts the flow of waste materials in the current Oshakati waste management system from generation to waste disposal or, alternatively, to recycling processes. According to the Recycle Namibia Forum (2014), an organization dedicated to promoting recycling throughout the country, a typical Namibian household can divert 60% to 80% of their total waste from the landfill through recycling. More developed areas have local processing facilities, while less developed areas may not have this resource and are forced to burn off excess waste material.

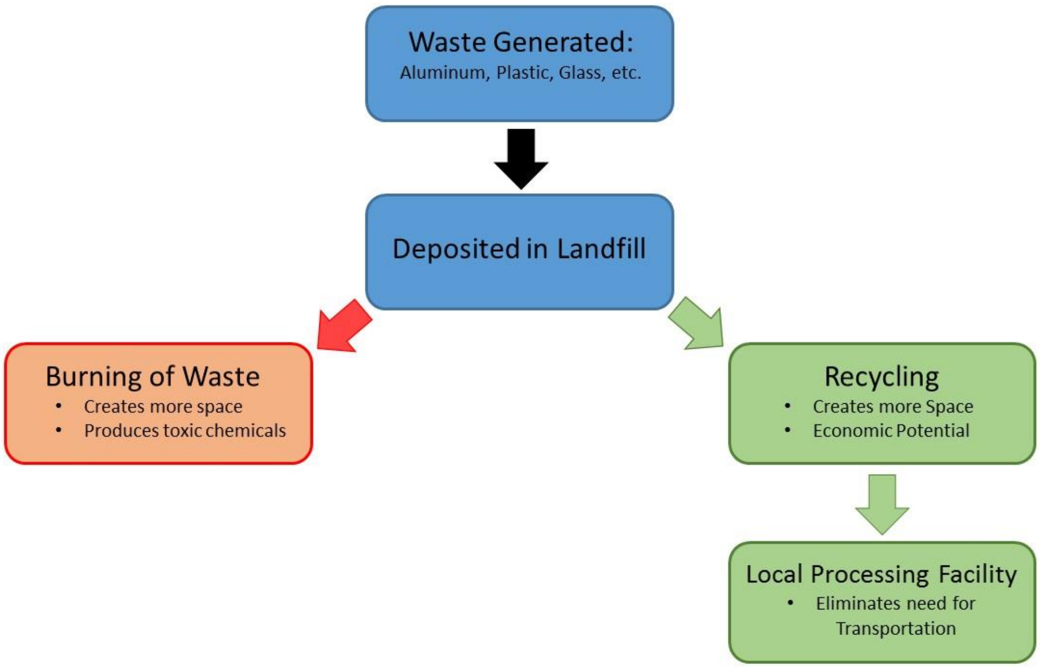

Figure 7: Recycling Flowchart

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 Minimisation, 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 8 depicts the results from a 2009 study on the composition of waste in Windhoek's landfills, which reveals that about 45% of the waste entering city landfills are recyclable materials (Hasheela, 2009). Recycling these materials reduces the amount of waste sent to landfills. To promote convenient recycling, RAD gives free bags to citizens to fill with recyclable waste. Waste management workers then collect the filled bags from households, replace them with clean new bags, and transport the materials to a recycling plant for processing (Shigwedha, 2010).

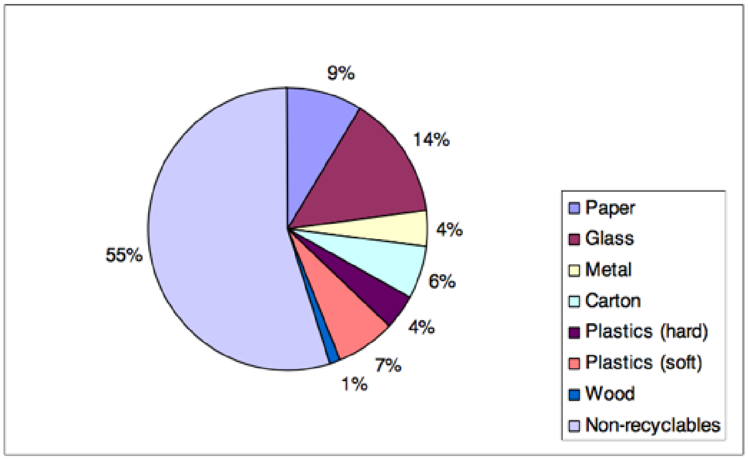

Figure 8: Recycling Waste Streams in Windhoek (Hasheela, 2009)

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 9 shows the prototype bicycle trailer developed by the students. The trailer has a 100-kilogram capacity, and costs N$2482.60, or US$190, to manufacture (Jacobsen et al., 2014).

Figure 9: Completed Recycle by Bicycle Prototype (Jacobsen et al., 2014)

The project team established pilot routes throughout Windhoek and IWCs tested trial rounds. On average, each bicyclist collected N$8.46 (US$0.65) of recyclables per hour (Jacobsen et al., 2014). The collection rate represents an increase of N$0.30 from what 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). About half of the total waste could be recycled. Figure 10 shows an estimated weight of total recyclable materials that are currently accumulating in the Oshakati landfill 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

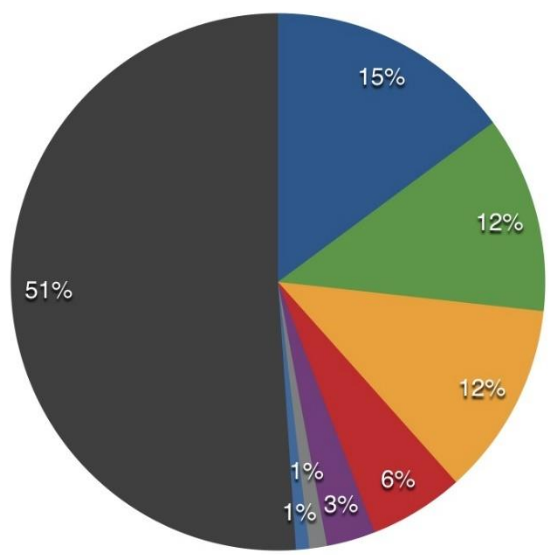

Figure 10: Materials Entering the Oshakati Landfill (adapted from Alsins et al., 2013)

IWCs and recycling companies work to recover as much of these materials as possible. Currently, 5287 kilograms of material per week are extracted from the dumpsite. This equates to about 30% of the available recyclable material delivered to the landfill (Haukena, 2017). In 2013, a team of students from NUST gathered data about the value and quantities of recyclables discarded in Oshakati. Table 3 uses this data to estimate the total potential value of recyclables in the Oshakati landfill, 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 landfill is just over N$289,000 (US$21,600) per year (Alsins et al., 2013).

Table 3: 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 this strategy could be applied to Oshakati. 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 landfill to N$1.81 per hour for an IWC using the bicycle cart to collect from households. This increase is greater than the pay increase observed in Windhoek (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."

2.3.4 Processing Recyclables Collected in Oshakati

Oshakati is one of the few cities in Namibia that has recycling packaging facilities. These facilities sort, package, and prepare recyclable materials for processing plants that turn them into useful products for industry. However, with no 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 both recycling packaging companies and IWCs. Each month, an Oshakati recycling company called Makalani Scrap Metal ships 30 to 40 tons of steel, plus an additional 30 tons of other metals, to Johannesburg, South Africa to be processed for industry

(Magen, 2010). The transportation alone costs N$24,000, or US$1,830, each month (Magen, 2010). RAD collects and ships 4,000 metal cans per month to facilities in South Africa, as well as 77,600 glass bottles per month to Dubai for processing (Magen, 2010).

Furthermore, some of these foreign processing companies ship industry-ready processed materials back to the Oshana region to be manufactured into goods. For example, Plastic Packaging LTD (PTY), a plastics manufacturing company in Oshakati, must pay to import extrudable plastic from suppliers in South Africa. A local processing program that could fully prepare recyclables for industry in Oshakati would minimize transportation costs and lead to increased earnings for IWCs.

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 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 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 nearly all of the recycled glass material, producing minimal waste. 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, 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 be used for the sorting and cleaning steps, and glass-crushing machines are simple and fairly inexpensive. For example, a CP Manufacturing glass crusher costs just N$35,000 (US$2,617) and can crush over 3,000 kilograms of glass per hour (CP Manufacturing, 2012).

2.4.2 Metals Recycling Processes

Aluminum and steel are the two most commonly disposed metals in Oshakati. Combined they make up about 50% of Oshakati's metal waste (Alsins et al., 2013). The recycling efficiency rate of both aluminum and steel is very high; nearly 100% of the material can be recovered through the recycling process without losing mechanical properties. The two metals are processed with nearly identical steps, however they melt at different temperatures and thus must be separated into different streams before this stage of the process. 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 commonly used in cans, cookware, housing, and car parts. Reforming recycled aluminum only uses about 5% of the energy and creates about 5% of the greenhouse gasses compared to creating aluminum from raw materials (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 reformable 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 (US$1,000) for a small furnace with the capacity to melt 3 kilograms of aluminum per hour, to N$137,850 (US$10,500) for a larger furnace that has the capacity to melt 100 kilograms of aluminum per hour (Alibaba, 2017; Made in China, 2017). Figure 11 shows an example of an aluminum processing machine that can block 10,000 kilograms of aluminum cans per hour. Determining the appropriate furnace capacity is essential to maximize profits from the aluminum recycling process.

Figure 11: 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 landfill 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 US$8,000 (N$104,788) to US$20,000 (N$262,775) or more (Alibaba, 2017). The recycling process of steel can be summarized in the following steps (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 12;
5. Molten steel is poured into molds to form blocks;
6. Steel blocks are melted and shaped to form new useful products.

Figure 12: Melting Furnace (Dynaform Technologies, Inc.)

2.4.3 Plastic Recycling Processes

Plastics account for about 12% of Oshakati's waste with 4,255 kilograms delivered to landfills 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 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 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 of a higher quality and require an additional sanitation step during processing. Plastic packaging for edible products must be manufactured with food grade plastics. 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, coming from recyclables such as 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 are immediately cooled and chopped into small pellets (Dan Ven Berg, 2009). Typically, a water spray quickly cools and hardens the plastic strands before they are chopped to produce 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 extrusion. Figure 13 shows a complete plastic recycling process.

Figure 13: Plastic Recycling Process (adapted from Haarman, 2015)

The town of Ahmedabad, India has an informal waste collection system similar to the one in Oshakati. IWCs in Ahmedabad run 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 14 (Vasave, 2013). The average pelletizer machine costs around N$105,030, or US$8,000 (Van Den Berg, 2009). This process is a simple and efficient way to recycle plastics for maximum return.

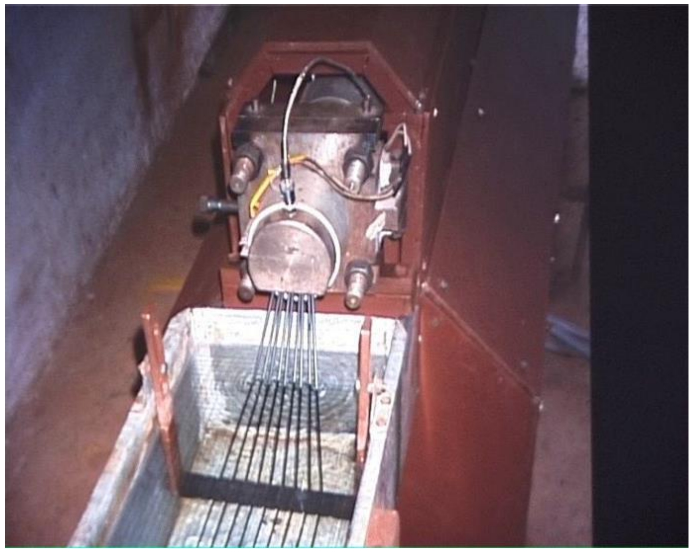

Figure 14: Example of Pelletizer Machine in India (Van Den Berg, 2009)

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

2.5 Summary

Oshakati's population and economic growth has caused a rapid increase in waste production. Without a formal recycling system, the dumpsites are overfilled. IWCs have found a way to generate income by searching through the town's dumpsite and collecting recyclables that they sell to recycling companies. These companies expend large amounts of money to ship the materials to South Africa for processing, resulting in decreased profits and extremely low wages for IWCs. A recycling processing plant in Oshakati could provide jobs and minimize material transportation costs for recycling companies, and ultimately improve earnings and working conditions for IWCs.

CHAPTER 3: METHODOLOGY

The project goal is to increase the earnings and livelihoods of informal waste collectors in Oshakati, Namibia, by integrating them into a restructured recycling processing system. The scope of this project limits the proposal of a "recycling processing system" to the following three elements:

1. Customer(s): The manufacturing company that purchases the processed materials for industrial use;
2. Process(es): The technique for preparing a particular recyclable material for industry, and the associated resources, equipment, and employment opportunities;
3. Investor(s): The company, organization, or entity that owns and operates the processing equipment or facility.

The ultimate project deliverable is a recommendation of the best combination of these three elements that will form a closed-loop system in the Oshana region, eliminate unnecessary costs, and provide increased earnings and livelihoods for Oshakati IWCs. The following objectives will guide the project:

Objective 1: To characterize existing systems and stakeholders in Oshakati;
Objective 2: To Evaluate Potential Strategies for Restructuring the Local Recycling Processing System;
Objective 3: To Prepare Recommendations for Integrating Informal Waste Collectors into the Recycling Processing System.

Figure 15 shows how the team will progress through these three objectives. The following sections describe the importance of each objective and how they will contribute to achieving the goal of the project.

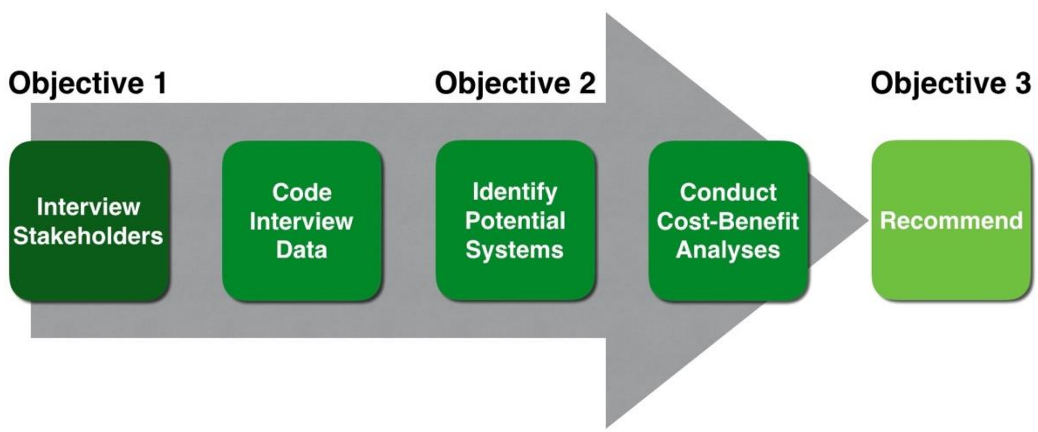

Figure 15: Methodology Flowchart

The timeframe for this project is March 11, 2017 through May 6, 2017. The project is a collaboration between Namibia University of Science and Technology, Worcester Polytechnic Institute, and major stakeholders in Oshakati. It is a continuation of a series of NUST Recycle by Bicycle projects that investigated recycling as a solution to the waste management problems in Namibian settlements. Building from the data in these prior projects, which Chapter 2 summarizes, the team believes that a plastic processing system would be most beneficial to the IWCs of Oshakati. Plastic is the second most abundant recyclable in Oshakati's landfill and earns the second-highest pay per kilogram from Wilco (Alsins et al., 2013 and Haukena, 2017). Of all recyclable materials collected by IWCs, plastic has the highest weekly gross potential profit for IWCs at N$1702, or US$131 (refer to Table 3 in section 2.3.2). Additionally, Plastic Packaging (PTY) LTD is located in Oshakati, so there is a local demand for industry-ready plastic materials. The implementation of a plastic processing system in Oshakati would eliminate the need for plastic to be shipped out of the town at anytime during the recycling process. In this new processing system, Oshakati's IWCs would focus on collecting and preparing the plastic for industry before selling the processed material to local manufacturers, such as Plastic Packaging (PTY) LTD. This would create a closed-loop plastic recycling system in Oshakati.

3.1 Objective 1: To Characterize Existing Systems and Stakeholders in Oshakati

Understanding the current waste management and recycling practices and technologies in Oshakati is a key first step to the project. Before proposing changes, it is important to fully understand the existing system, which will provide a foundation for the restructured recycling system. This first objective assesses the available resources, perspectives, and requirements of stakeholders.

The team must identify and interview the project stakeholders with the intention of receiving as much helpful information as possible. Chapter 2 provides extensive literature reviews and case studies that will help the team conduct thoughtful and informative conversations with stakeholders. In the second week of the project, the team will travel to Oshakati to conduct stakeholder interviews and determine what roles each stakeholder plays in the existing waste management system. This investigation will discuss what the stakeholders are interested in improving, how each stakeholder could be affected by a restructured recycling processing system, and each stakeholder's potential interest in a contributing to a restructured recycling processing system. The project team will consider all of this information when recommending a new recycling processing system in Oshakati.

3.1.1 Select Interview Subjects

Any individuals, companies, or entities involved in the current Oshakati recycling system are stakeholders of this project. Figure 16 illustrates the flow of materials and money in the waste management system in Oshakati, highlighting the key stakeholders. This section briefly introduces the key stakeholders to be interviewed.

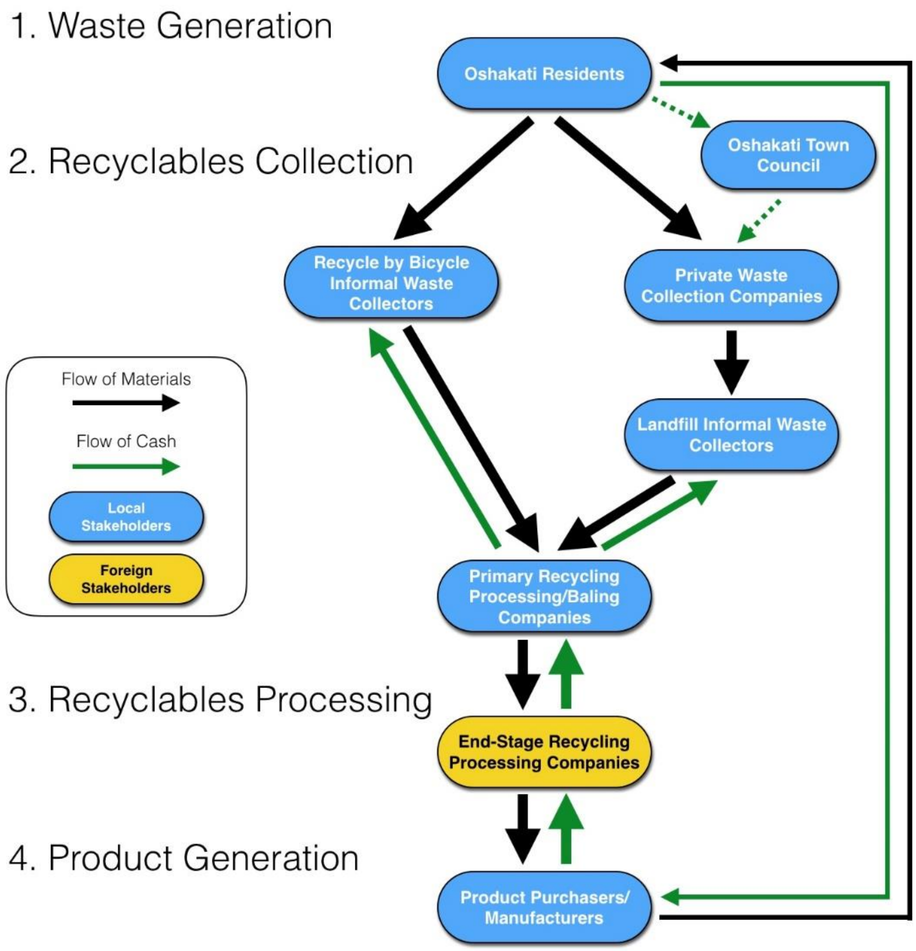

Figure 16: Flow of Materials and Cash in the Oshakati Recycling System

Informal Waste Collectors (IWCs)

This project intends to improve the quality of life for IWCs by improving their working conditions and income. In the current system in Oshakati, IWCs initiate the recycling process by collecting recyclable materials from the dumpsite. If there was a system through which they could process these recyclable plastics locally, the sale value of their materials would increase, thus improving their earnings. Therefore, IWCs are the intended employees for a potential plastic processing plant. The specific skills, needs, and suggestions of IWCs will heavily influence the recommended recycling system design. Now that the Oshakati Recycle by Bicycle initiative has grown from one bicycle to three, interviewing both bicyclist IWCs and dumpsite IWCs will identify differences in their views.

Recycling Packaging Companies

Another important group of stakeholders to interview are independent recycling packaging companies in Northern Namibia. These companies either collect recyclables directly from households and businesses, or purchase them from IWCs operating in the landfill. All recycling packaging companies in Oshakati currently bale and package the materials for transportation to end-stage processing facilities. RAD and Wilco are particularly important companies to consider during this study, as they are the two companies that buy the most materials from IWCs. The study will explore where their interests lie, as they are potential investors for a more advanced recycling processing system.

Each of these companies could have one of two initial reactions to the prospect of a new recycling program in Oshakati. They could see a new system as an opportunity to invest and expand their current operations and profits, or as a threat to their current business if it is owned by a competing company or organization. In either case, each company can give the team insight regarding the current recycling system in Oshakati, potential customers, and potential investors.

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 local economy and to minimize transportation costs. One example of a potential customer is Plastic Packaging (PTY) LTD in Oshakati, introduced in Chapter 1. The purpose of talking to these potential customers is to learn about the materials they currently purchase and how they choose material suppliers. The interview will discuss their material quality requirements, volume consumption, price point, and investment potential. Essentially, these customer interviews will gather the necessary data to establish the quantity and quality of the materials the proposed process should produce. The team will be able to gauge their interest in purchasing locally recycled materials, and potentially estimate how much they would willing to pay for these products, both of which will influence the cost-benefit analysis and final recommendations.

Oshakati Town Officials

The local government in Oshakati determines the local waste management laws, so the team must consider their views about recycling in Oshakati. They can facilitate understanding existing laws and make suggestions about the requirements and restrictions for a restructured recycling processing system in Oshakati. The interviews will also inquire about the town's interest in, and available resources for, investing in a local recycling program. The team will interview Town Council members and other relevant town officials to gauge interest in assisting the team with the project.

3.1.2 Interview Key Stakeholders

All stakeholders will be asked a set of common questions to understand their view on overarching topics. These questions aim to collect information about the different roles that each stakeholder obtains in the current Oshakati waste management system. The investigation will discover the changes or improvements they have tried, what they have learned from these attempts, and if they see a new recycling processing program as having the potential to improve waste management and stimulate economic growth. The following are some common questions the team will ask all of the interviewed stakeholders:

- What role(s) do you or your company serve to the waste management process in Oshakati?
- What types of recycling processing are you or your company conducting today?
- What strategies have you or your company considered for improving your recycling process whether it be collecting, processing, or shipping?
- What improvements to the recycling process could benefit you or your company?
- What are your thoughts about a local plastic recyclable processing system?
    - Would you be interested in investing or partnering in such system?

Additionally, the team will develop specialized questions for each stakeholder to address the unique perspectives and expertise of each individual or company involved in the waste management system. Some questions will be focused on labor and collection, others on management and processing. Table 4 shows preliminary questions for each stakeholder. Appendix A contains a full list of interview questions for each stakeholder.

Table 4: Sample Stakeholder Interview Questions

Stakeholder	Questions

Informal Waste Collectors	• What does a typical workday include?
	  • How long is a workday?
	  • What are some concerns you have about working in the dumpsite?
	• What roles do different IWCs have?
	• What types of organization strategies do you use in your job?
	• How many different companies do you work with?
	  • Which company do you prefer to sell your recyclables to?
	    • Why this company?
	• How are you compensated for the materials you sell?

Recycling Packaging Companies	• What process do you follow for the collection of recycling materials?
	• What type of processing do you currently use on the materials you collect?
	• Who do you sell your processed materials to?
	  • What price do they pay you for each material?
	  • Does quality of material affect price?
	  • Could you receive more if you processed materials further?
	• Would your company be interested in investing in a plastic processing system?

Manufacturers/Potential Customers	• What materials do you use for manufacturing?
	• Who are your suppliers?
	  • How much do you pay for each material?
	• What quality standards do you have for the materials you purchase?
	  • How are these standards tested?
	• Would your company be interested in partnering with or investing in a local plastic recycling system?

Oshakati Town Officials	• What role does the town currently play in waste management and recycling in Oshakati?
	• Are you supportive of groups such as Informal Waste Collectors who search the dumpsite for recyclables?
	  • Have you ever interacted with them?
	  • Are there any regulations to protect them?
	  • What positives and negatives do they bring to the town?
	• How would the town be able to support or contribute to a new recycling processing program in Oshakati?

3.1.3 Consider Cultural Differences and Ethics

To conduct successful interviews, it is important to understand cultural differences and ethical considerations when interacting with local stakeholders. The team will be as respectful as possible and understands the impact that foreigners can have when questioning a foreign town about their waste management and economic situations. Most of this project's ethical concerns involve interactions with IWCs. The interviews must be respectful of the interviewees' work and lifestyle, and be especially appreciative of their time. By taking the time to talk to us, these individuals lose working time and earnings. Sensitivity to their economic situations when collecting data about IWC earnings is imperative. The questions will be respectable and time-efficient.

The team will also present thoughtful questions to private recycling and waste management companies, as they could become defensive or suspicious about the project. If they see the project as leading to potential competition, they will not contribute to the project. To prevent this from happening, the team will phrase questions to emphasize the business potential that could be provided by a restructured recycling processing system in Oshakati.

The team will obtain full consent of the interview subjects by fully explaining the project goals, the types of information the team is collecting, and how the team will use this data. Appendix C contains the informed consent script that will convey this information to the interviewees and gain their full consent.

3.2 Objective 2: To Evaluate Potential Strategies for Restructuring the Recycling Processing System

The team will evaluate and code the data collected in the stakeholder interviews to determine the most appropriate processing system for the town of Oshakati. The coded interview data will guide the process for identifying and evaluating potential strategies for restructuring the Oshakati recycling processing system. The beginning of Chapter 3 defines a "recycling processing system" for the scope of this project as a combination of a customer, a process, and an investor. This phase of the project includes identifying potential customers, choosing the most advantageous recycling process, and narrowing down the list of potential investors. The systems the team will consider for recommendation will be both economically viable for investors and beneficial for the employed IWCs.

3.2.1 Organize and Analyze Data from Interviews

The team will summarize, consolidate, and code the information from the stakeholder interviews. Table 5 will organize the data based on a topic's importantance to each stakeholder. This table lists the major themes, facts, or concerns discussed in the interviews, and ranks them based on importance, as expressed by each stakeholder. These themes will be the pre-set codes, shown in the leftmost column of Table 5, as well as any emergent codes expressed by the stakeholders in the interviews. The team will sort all interview findings into the code categories and rate each finding on a scale of zero to five from the perspective of each stakeholder. A zero indicates that it is a nonconcern and a five indicates that it is significant to that stakeholder's interest. Additionally, the team will assign each stakeholder a weight percentage, designating which stakeholders are most influential to the project and recommendations. The table computes the weighted sum of the rankings for each data piece. The final weighted sums allow the team to rank the findings by overall importance to the project.

Table 5: Table for Organizing Coded Interview Data

Code/Theme	Fact, Concern, or Idea	Importance as Expressed by Each Stakeholder (1-5, 5 = Very Important)				Weighted Importance
		IWCs	Recycling/Waste Management Companies	Product Purchasers	Oshakati Town Officials	Weighted Sum
Economic		0	0	0	0	0
		0	0	0	0	0
Livelihood		0	0	0	0	0
		0	0	0	0	0
Processes		0	0	0	0	0
		0	0	0	0	0
Output Products		0	0	0	0	0
		0	0	0	0	0
Demographics		0	0	0	0	0
		0	0	0	0	0
	Weighted Value of Stakeholders (%):	40	25	25	10	

3.2.2 Determine Potential Systems to Consider

The team will identify manufacturing stakeholders who express an interest in purchasing locally recycled plastics to determine the potential system. The plastic demands of these customers will limit the number of applicable plastic recycling processes. Based on this information gathered from stakeholder interviews, the team will develop a list of possible processing techniques for plastic. If any stakeholder expresses the need for a different material to be processed, the team will also evaluate that type of material processing. Chapter 2 describes some primary processing ideas, and case studies and literature reviews will provide more examples and data for potential processes.

3.2.3 Evaluate Potential Systems

This investigation includes a cost-benefit analysis of each potential system established in the previous section. A cost-benefit analysis determines whether an endeavor is worthwhile by totaling and comparing benefits and costs. This analysis is a systematic approach to determine the strengths and weaknesses of each potential system and will produce a cost-benefit ratio for each system as a unit for comparison. A system is deemed beneficial if the cost-benefit ratio is greater than 1, meaning that the benefits outweigh the costs of the process. This cost-benefit analysis will examine the initial implementation of the recommended system as well as the operation over the next several years. Initial and annual costs such as machinery, IWC training, and transportation costs, will be examined along with benefits such as annual revenue. The analysis will factor in nonmonetary benefits such as safety and social considerations. The team will evaluate stakeholders' opinions to assign a weighted monetary value to each nonmonetary benefit. Appendix C contains the complete calculations spreadsheet the team developed to conduct the cost-benefit analysis.

3.3 Objective 3: To Prepare Recommendations for Integrating Informal Waste Collectors into the Recycling Processing System

After computing the cost-benefit ratio for each process, the team will present the top contenders to the project sponsor. Since the cost-benefit analysis includes the stakeholders' monetary and non-monetary criteria, the best resulting analyses will determine the most viable processing systems. The team will assess each of the systems with the highest cost-benefit ratios to determine what employment opportunities they can offer IWCs. Using the cost-benefit results and IWC employment considerations, the project team and sponsor will select the most appropriate recycling processing system to recommend for Oshakati. Finally, the team will identify potential investors for this system and prepare final recommendations for the restructured system.

3.3.1 Determine Informal Waste Collector Roles in Recycling Processing System

IWCs are the intended employees of the recycling system. The final deliverable will indentify the roles IWCs can contribute to the system, and estimate the number of workers the process can employ. Assessment of IWC skills and preferences will determine what types of jobs will be appropriate. The team will consider the following traits of the proposed processes:

- Necessary literacy levels;
- Necessary technical or working skills and associated training;
- Required amount of manual labor;
- Other concerns expressed by IWCs during interviews.

The system recommendation will consider the different roles that are available in the recycling process and match them to the skills, concerns, and requests of IWCs, using information from the stakeholder interviews. The team will develop a list of potential jobs for IWCs offered by each system, as well as a list of the necessary skills and training associated with each opportunity.

3.3.2 Select the System for Recommendation

The next phase of this project involves presenting the contending processes and associated employment evaluations to the project sponsor. The team and sponsor will discuss the analysis results, the pros and cons, and the IWC roles in each contending system. This discussion will determine the final process and system to recommend for Oshakati. The chosen system will be the one that best reflects the project goals, while also being economically profitable and appealing to potential investors. If during this discussion any concerns arise with the proposed options and no final selection is made, the team will return to Objective 2 and reevaluate the weights of different factors in the cost-benefit analysis or consider other material or processing options.

3.3.3 Determine Potential Investors for the Processing System

A restructured recycling processing system in Oshakati requires funding from an established entity that is interested in furthering the mission of this project. Potential investors for this processing system include the Town of Oshakati and private recycling or waste management companies in Oshakati or the Oshana region. The methods in Objective 2 will determine whether or not a private recycling company, such as RAD or Wilco, could benefit from incorporating a processing system into their current business model. This final phase of the project will recommend the potential investors who are most likely to benefit from the venture and uphold the mission of the project. In order to achieve the project goal of improving IWC livelihoods, the investors must fulfill the following standards set by the team:

- Investor must employ IWCs;
- Investor must pay employed IWCs higher wages than what IWCs currently earn from collecting recyclables from the dumpsite and selling to private recycling packaging companies;
- Investor must enforce and monitor safe working conditions for IWCs;
- Investor must supply clean running water to provide workers with access to sanitation;
- Investor must provide appropriate management and maintenance for the operation of the processing equipment or facility;
- Investor must have the necessary finances and resources to establish and operate the processing equipment or facility;
- Any other standards the team develops after coding stakeholder interviews.

This relationship between the investor and the IWCs would be mutually beneficial. The investing company would earn additional revenue through processing the materials that they collect rather than having to transport them for processing. Under management from a company or organization, IWCs would have the opportunity to work in a safer environment and to earn a higher income. In addition to the initial capital investment, the investing entity will be able to offer its managerial structure to better organize the system. This type of investor will integrate IWCs directly into a formal recycling processing system in Oshakati.

3.3.4 Present Optimal Findings to Sponsor

The final deliverable to the project sponsor will be recommendations for a restructured recycling processing system in Oshakati, in the form of a written report and presentation. The recommendations will discuss the selected plastic recycling process, the cost-benefit analysis results, a description of IWC employment opportunities, and a refined list of potential investors.

The report will include information about the types of plastic (or other material) processed, the equipment and resources required by the recommended recycling process, the products output by the process, and potential customers of the system. Hopefully, the cost-benefit analysis will indicate that the recommended system is economically viable. Since this analysis also considers non-monetary factors the cost-benefit results will also attest to the safe and sanitary working conditions of the proposed process. Additionally, the list of IWC employment opportunities will show how the proposed plastic processing system can integrate IWCs to enhance their livelihoods. Finally, the recommendation report will discuss the list of possible investors who have the required resources and who are likely to accomplish the project goals.

The team will submit these deliverables to the project sponsor. The sponsor will then be able to use written report and presentation materials to present the recommended system to the appropriate stakeholders. They can use these materials to find investors and begin implementing the restructured plastic processing system in Oshakati.

3.4 Summary

This project's mission is to increase the earnings and livelihoods of informal waste collectors in Oshakati by integrating them into a restructured recycling processing system. To accomplish this goal, the team will first conduct interviews with key stakeholders in Oshakati to develop a better understanding of the current waste management system. These interviews will set guidelines for possible recycling systems. A weighted ranking system of the data findings will establish the most important factors, which will help identify potential plastic processing systems. The team will conduct a comprehensive cost-benefit analysis to determine the most advantageous systems and evaluate IWC employment opportunities for each of the leading processes. Then the team and project sponsor will select the final system to recommend. The team will identify potential investors for this selected system, and prepare recommendations for a restructured plastic processing system in Oshakati.

BIBLIOGRAPHY

Alibaba (2017). Fast Speed Aluminum Melting Machine. 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 from http://www.azom.com/article.aspx?ArticleID=7979

Central Intelligence Agency. (2014.) The World Factbook -- Central Intelligence Agency. https://www.cia.gov/library/publications/the-world-factbook/fields/2129.html

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

Consol Co. (2014). Glass Recycling. Retrieved from http://www.consol.co.za/business/why-glass/glass-recycling

CP Manufacturing, (2012). Glass Crusher. Retrieved from http://www.cpmfg.com/recycling-equipment/aluminum-can-recycling-machines/

Dynaform Technologies, Inc. (n.d.). *Melting Furnace*. Retrieved February 13, 2017, from http://www.dynaformtech.com/files/freestyle/melting-furnace.jpg

Environmental Management Act (EMA) (2007). Environmental Management Act No. 7 of 2007. Government Gazette, 27 December 2007. Republic of Namibia.

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

Haarman, Arthur (July 2015.) Towards Sustainable Plastic Recycling in India: Experiences from the Field. Sustainable Recycling Industries. Delhi, India.

Hangula, N. (2000). The Impact of War on the Ohangwena Region. *Public History: Forgotten History*.

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

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

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.

International Aluminium Institute, et al. (2009). Global Aluminum Recycling: A Cornerstone of Sustainable Development. 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 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. 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.

[Map of Namibia]. (1998). Retrieved from https://www.britannica.com/place/Namibia

Moreno-Sanchez, R. D. P., & Maldonado, J. H. (Jun 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(11.3), 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.

Oshakati, Namibia (2017). Google Maps. 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

Oshana, Namibia (2017). Bing Maps. 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

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.

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.

The World Bank, World Development Indicators (2017). *GDP (Current US$)* [Data file]. Retrieved 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: STAKEHOLDER INTERVIEW QUESTIONS

Informal Waste Collectors

1. How often do you work, days a week and hours per day?
2. What does a typical workday include?
    a) What are some concerns you have about working in the dumpsite?
3. What role do IWCs serve to the waste management process in Oshakati?
    a) What different roles do different IWCs have? Ex. Supervisors, collectors, sorters etc..
4. What is the male to female breakdown of IWCs?
    a) What is the age range of IWCs?
    b) Are there any restrictions for who can work as an IWC?
    c) How long have you worked as an IWC?
5. In what ways have IWCs considered improving the recycling collection process?
    a) What ideas have been successful, and what ones have not worked?
6. What improvements to the recycling process could benefit you?
7. What types of organization strategies do you use in your job?
8. How many different companies do you work with?
    a) Which company do you prefer to sell your recyclables to?
        1. Why this company?
9. How are you compensated for the materials you sell?
10. What are your thoughts about working in a local recycling processing system?
    a) Would you be interested in partnering in such a system?
11. What other jobs have you had experience with?
    a) What skills were necessary for those jobs?

Recycling Packaging Companies

1. What role does your company play in the waste management and waste management system of Oshakati?
2. How do you collect your recyclables?
    a) Who do you employ/partner with?
3. What type of recycling processing does your company provide?
4. Where do you send your processed materials?
    a) What further processing is performed?
    b) How much do you sell your processed materials for?
    c) What do you currently spend on product transportation?
5. What improvements to the system would benefit your company?
6. What improvements would make the system better for the Oshakati community?
7. What have you seen tried in the past to improve the recycling system or your job?
    a) What has worked and what has not?
    b) Why do you think these succeeded or failed?

8. Do you support the Recycle by Bicycle initiative?
    a) Why or why not?
9. Would you support a local recycling processing system?
    a) Why or why not?
    b) How would this benefit or harm your company profits/operations?
10. Would your company be willing to invest in a plastic processing system?
    a) Why or why not?
    b) Would you be willing to own or partner with such a system?
11. Would your company be willing to invest in a different material processing system?

Manufacturers/Potential Customers

1. What role do you feel your company plays in the waste management and recycling system in Oshakati?
2. What improvements to the Oshakati recycling process could benefit you or your company?
3. What materials do you use?
    a) How much do you use?
    b) Where do you purchase these materials?
    c) Who do you employ/partner with?
    d) Where do these materials originate?
    e) What do you currently spend on product transportation?
    f) What percentage of recycled materials do you use?
4. What have you seen tried in the past to improve the system or your job?
    a) What has worked and what has not?
    b) Why do you think these succeeded or failed?
5. Would you support a local recycling processing system?
    a) Why or why not?
    b) How would this benefit or harm your company profits/operations?
6. Would you be willing to use local recycled materials as one of the suppliers for your company?
    a) What requirements might this recycling system have to consider for you to use them?
7. What quality material is necessary?
    a) What tests do you conduct for material quality?
    b) What prices would you pay for a locally produced, recycled material?
8. Would your company be willing to invest in such a system?
    a) Why or why not?
9. Would you be willing to own or invest into such a system?

Oshakati Town Council

1. What role do you feel the council plays in the waste management and recycling system of Oshakati?
2. How is waste collected?
    a) Who do you employ/partner with?
    b) How much money do you spend on waste collection?
3. Do you interact with IWCs?
    a) What regulations are in place to protect them?
    b) What problems or advantage do they present to the town?
4. What improvements to the system would benefit the town?
5. What improvements would make the system better in general?
6. What have you seen tried in the past to improve the system or your job?
    a) What has worked and what has not?
    b) Why do you think these succeeded or failed?
7. Do you support the Recycle by Bicycle initiative?
    a) Why or why not?
8. Would you support a local recycling processing system?
    a) Why or why not?
    b) How would this benefit or harm the town?
9. Would the local government be willing to invest in such a system?
    a) Why or why not?
    b) Would you be willing to own or partner with such a system?
10. Do you believe a government-run or privately-run system would be most successful?
    a) Why or why not?

APPENDIX B: 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 Oshakati. We hope this research will ultimately improve the local waste management system and contribute to improving the livelihoods 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 C: COST-BENEFIT ANALYSIS SPREADSHEET

1. Insert process costs for each year under the appropriate column and row.
2. Insert process benefits for each year under the appropriate column and row.
   a) Nonmonetary benefits will be assigned a monetary value based on the importance identified by the stakeholders.
3. The yellow highlighted cell provides the total cost-benefit ratio over the 10 year span.
4. Repeat steps 1-3 for each process alternative and compare total cost-benefit ratios.

	Fiscal Year											
Costs	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Initial Facility Cost												0
Initial Machine Cost												0
Training Cost												0
Repair Cost												0
Employee Wages												0
Total	0	0	0	0	0	0	0	0	0	0	0	0

Benefits	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Profit												0
Safety Factor												0
Other Benefits Identified												0
Total	0	0	0	0	0	0	0	0	0	0	0	0

Analysis	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Total
Cost-Benefit Ratio	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!