Recycling by Bicycle: A Green Alternative to Expand Recycling and Create Jobs in Windhoek

An Interactive Qualifying Project Report submitted to the Faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

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Abstract

Unemployment and inefficient recycling practices are significant problems in Namibia. Our project goal was to model the integration of informal waste collectors into the formal collection system through collecting recyclables using bicycles, which could reduce the use of fossil fuels and generate jobs in Windhoek. We tested this idea through a pilot program utilizing an informal waste collector volunteer. Our recommendations aim to help the Polytechnic of Namibia move forward with the model of recyclable collection by bicycle.

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- Logan Roche – Editing the report
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Executive Summary

With over 27 percent of the population lacking a job, unemployment is a major concern in Namibia (Namibia Statistics Agency, 2013). Due to this, many Namibians have sought out informal, or unregulated jobs, as a means for income. One major form of informal work is the collection and resale of recyclable materials, known as informal waste collecting. Informal waste collectors operate around the city of Windhoek, collecting bottles, cans, and other recyclable materials from household trash bins, or in the landfill. Their working conditions are dangerous, unpleasant and provide a very minimal income.

Solid waste management poses several challenges for the City of Windhoek. One of the foremost issues is that although Windhoek has a recycling provider, the practice has yet to take hold in significant numbers. Rent-A-Drum, Namibia's primary recycling company, has established a clear bag system for both businesses and households to utilize for the disposal of recyclable materials. Rent-A-Drum collects the clear bags, brings them to their material recovery facility, sorts the different recyclables, and sells the materials to processing plants to be reused.

The Polytechnic of Namibia seeks to unite these two issues of unemployment and recycling by creating green, reliable jobs in the recycling industry. The Department of Agriculture and Natural Resources Sciences at the Polytechnic has fostered the idea of using bicycles to collect recyclables from households in Windhoek. The use of bicycles could potentially decrease the environmental impact of recyclable collection by truck, which consumes fossil fuels inefficiently. Additionally, this could create a small industry that would generate more jobs for the unemployed.

The goal of this project was to design a model for integrating informal waste collectors into the formal collection system through the use of bicycles for recyclable collection. To reach

this goal we accomplished a set of objectives. We began by assessing the current waste management systems in Windhoek and identifying the current practices of informal and formal waste collectors. We then developed a transportation prototype for collecting waste. Upon completion of our prototype, we designed and operated a pilot program for collecting recyclables. We analyzed the social acceptability of the pilot program and determined the potential economic and environmental benefits.

We accomplished these objectives through an assortment of methods including interviews, participant observation, direct manufacturing of the prototype cart, and piloting the bicycle collection. Initially, we interviewed several parties of key informants to further our understanding of waste management in Windhoek. These groups included employees of the City of Windhoek's Solid Waste Management Division, the Bicycle Empowerment Network of Namibia, the Recycle Namibia Forum, and Rent-A-Drum. Subsequently, we interviewed a cooperative of informal waste collectors operating in the landfill to learn more about their working conditions and their opinions on our project.

With input from two Polytechnic of Namibia design students, we designed and manufactured the bicycle cart attachment that was used for the recyclables collection pilot program. It is a steel structure with a canvas bag capable of hauling up to 100 kilograms. We planned and operated two separate pilot programs utilizing a volunteer from the informal waste collector cooperative. The first pilot test

Figure 1: Helmut operating the bicycle cart

worked with Rent-A-Drum to supplement the truck collection of their clear bags. The second tested independent, at-the-source collection by sorting out recyclables from household waste bins. All collected materials were weighed and sorted to assess the resale value.

From our piloting operations, we found that both initiatives were feasible. Even with the effort of biking a fully loaded cart uphill, bicycle waste collection, in the opinion of our informal waste collector volunteer, Helmut, created improved working conditions compared to those of the landfill. Additionally, we found that Helmut generated slightly more value in recyclables per hour by removing recyclables at-the-source rather than at the landfill, where materials are buried before retrieval and he makes numerous sorting trips on foot. Additionally, we found that Helmut generated slightly more value in recyclables per hour by removing recyclables at-the-source rather than at the landfill. This indicates that at-the-source collection could become a reliable source of income.

Figure 2: Helmut during the Rent-A-Drum pilot trial

We were able to demonstrate the effectiveness of recyclable collection by means of bicycles and construct a model for the operation of this system. From our model, we developed a set of recommendations for the project. We recommend that the system of bicycle collection be used to bring recycling to areas that currently have none, including informal settlements, where trucks are unable to collect due to narrow dirt roads, or other regions of Namibia that are looking to recycle but lack the support of a recycling enterprise. We also recommend investigating the

potential for a bicycle cart industry for the manufacturing and maintenance of the carts. Additionally, the use of the cart should not be limited to recycling and research should be performed on alternative uses. The findings and recommendations from our study may enable the Polytechnic to move forward with the implementation of the project to reduce the environmental impact of recyclable collection, while also creating opportunities for the unemployed.

1.0 Introduction

Unemployment and poor solid waste management are two of the most significant problems faced by developing nations around the globe (Rabinovitch, 2013). The majority of jobs are located in urban centers, which causes a high rate of migration towards cities. However, urban areas lack a sufficient number of jobs to employ all of the large influx of people. This phenomenon of urban migration is leading to increased unemployment rates as well as unsafe living conditions. Many cities in developing countries do not have the facilities or resources to handle the increased waste production from the growing population. Therefore, management of municipal solid waste, or garbage produced by the general public, suffers as a result of increased urban overcrowding (Rabinovitch, 2013). Namibia experiences this exact unemployment, migration, waste management scenario.

Over a quarter of the population of Namibia is currently unemployed (Namibia Statistics Agency, 2013). As a result, many Namibians resort to other, less conventional, means of making a living by participating in an informal economy, which is any part of an economy that is not taxed or monitored by the government (Princeton, 2012). In Windhoek, the capitol of Namibia, one key job within the informal economy is informal waste collecting. People who work as informal waste collectors earn an income by sorting through garbage to find recyclables that can be resold for a profit.

Informal waste collecting is a difficult, dirty, and unsafe method of making a meager living for unemployed people in Windhoek (Moreno-Sanchez, 2006). Consequently, many organizations are sponsoring efforts to improve their working conditions, often through employing the workers formally. The Polytechnic of Namibia is working to improve the working conditions of informal waste collectors through the creation of more jobs in the waste collection

sector. The Polytechnic of Namibia sees the potential in creating jobs while also decreasing the environmental impact of waste collection by supplementing fuel inefficient trucks with bicycles. They are beginning the foundational work on a long term study about employing informal waste pickers as bicycle waste collectors in the formal sector.

The overall goal of this project is to explore a process to integrate the informal waste collectors into the formal collection system. This project could lead not only to job creation for the unemployed, but also to an improved waste management system in Windhoek. There are a variety of different examples around the globe of formal and informal waste collection integration through the use of bicycles; however, little research has been performed on bicycle waste collection in Windhoek. In order to evaluate the effectiveness of a program such as this, we laid out the following objectives: (1) to assess the current waste management system in Windhoek, (2) identify the current practices of informal and formal waste collectors, (3) develop a transportation prototype for collecting waste, (4) design and operate a pilot program implementing the prototype, (5) analyze the social acceptability of the pilot program, and (6) determine the economic and environmental benefits of the pilot program.

In the subsequent chapters we begin to detail the background information needed to fully understand the ideas and concepts related to our goal and objectives. Following that, in Chapter 3 we provide details of the methods used to complete our objectives. Chapter 4 details the specifics of our design and manufacturing processes. The results of our project and our findings are shared in chapter 5. In Chapter 6, we discuss our conclusions and recommendations about bicycle collecting as viable alternative. The information from our study shows the potential for reducing the associated costs of recyclable collection while simultaneously creating jobs for informal waste collectors in Windhoek.

2.0 Background

Unemployment and waste management are two major problems that are plaguing the country of Namibia and specifically the informal settlements on the outskirts of Windhoek. In this chapter, we discuss the causes of unemployment and how high unemployment rates have led to the establishment of an informal economy. Within the informal economy of Windhoek, we focus specifically on the informal waste collectors and their role in the overall waste collection system. We then discuss the formal sector of waste management and the drawbacks of the current system in Windhoek. Lastly, we address a potential supplement to the current formal waste collection system and how this can be integrated with the informal system to create jobs and decrease the environmental impact of waste management.

2.1 Unemployment

Namibia is considered a middle-income country, but statistics seem to contradict this classification. The top 10 percent of the population control almost half the wealth in the country (Health Poverty Action). Namibia suffers from a high degree of economic inequality and a high unemployment rate. According to a UNICEF survey conducted in 2010, one in three children in Namibia grows up in a poor household (Namibia Statistics Agency, 2012). Beyond that, as of 2008 almost a third of the population of Namibia lived on less than one US dollar (USD) per day, and a growing number of people lived in "severe poverty" where the household subsisted on less than 19 USD per month (IRIN, 2008). The high rate of unemployment contributes to this significant economic inequality within the population and the formation of informal settlements within the large cities of the nation. In 2012, the broad unemployment, which includes all the people in a country who are not employed at any time, was 27.4 percent (Eita, Jowl Hinauye,

2010; Namibia Statistics Agency, 2013; CIA, 2014). Over the last ten years the broad unemployment rate has fluctuated greatly as shown in Figure 3 below.

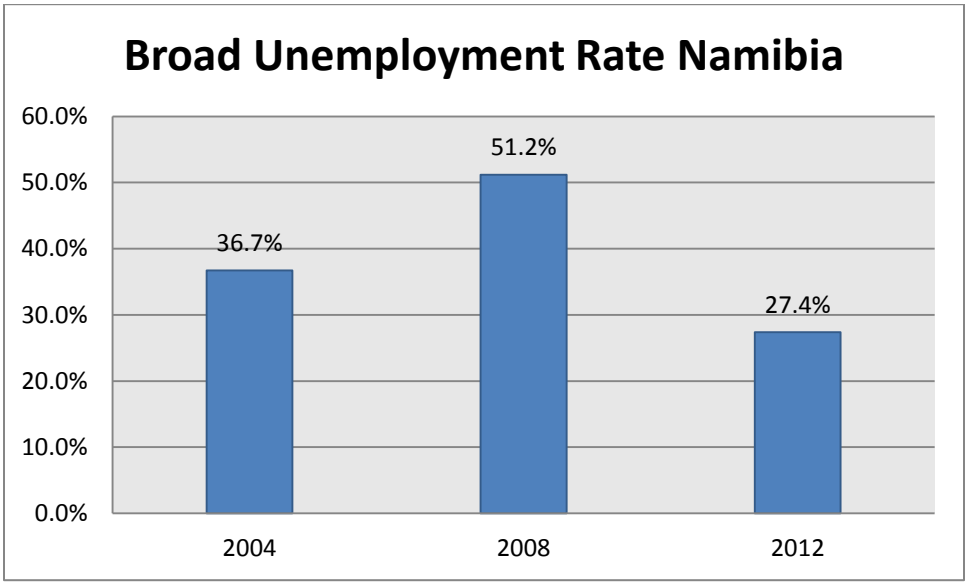

Figure 3: Unemployment rate in Namibia years 2004, 2008 and 2012, graph: Namibia Statistics Agency, 2013

2.1.1 Causes of Unemployment

There are many different causes of unemployment. One major cause is the lack of knowledge or appropriate marketable skills, which often stems from insufficient education (Economics Help, 2014). Statistically, there is a distinct worldwide trend where people with an education earn more than those without a degree (Bureau of Labor Statistics, 2013). The lack of quality education in Namibia is a significant problem in both rural and urban communities. Namibia has a large rural population. Not only is transportation a great challenge resulting in lower school attendance, but poor rural communities struggle to supply educational resources and proper facilities (Fischer, 2010; Ipinge, 2013) The struggling education system in Namibia plays a large role in the high numbers of unskilled workers and high unemployment rate.

The causes of unemployment are not limited to a lack of skills and education; unemployment is also linked to geographical location. Geography becomes a cause of

unemployment when jobs are available in one area, but the people live elsewhere. This spurs migration in the hope of finding employment (UNFPA, 2013). However, if too many people move to the same area, the job market will become saturated, contributing to increased unemployment numbers and unemployment in a region.

This phenomenon can be seen within Katutura, the informal settlements in Windhoek. Informal settlements are unstructured, typically impoverished housing developments often built on the outskirts of large cities, which segregates them from the centers of urban activity.

Figure 4: Katutura Township

The issue of a geographically clustered, predominantly unskilled workforce goes back to the time of Apartheid. Restrictions from the Apartheid era required non-white Namibians to live in townships, growing up in poverty in the informal settlements and limited in their education, job options, and place of residence. With the removal of the Apartheid laws in the 1980's, families were able to move freely within Nambia (Niikondo, 2010). This marked a rapid growth of the informal settlements, which grew at the periphery of the apartheid era townships as people moved to the capital for the potential increased job opportunities (Community Land Information Program, 2009; Bruce and Wade, 2002). But the effects of many years of poorer education and limited job options will take time to overcome.

2.1.2 Informal Economies

Unemployment and unstable income in the informal settlements of Windhoek has led to the establishment of a thriving informal economy which in 2006 provided an income for at least 133,000 Namibians (Brigitte Weidlich, 2006; Simon, 2008). An informal economy is the portion of a nation's economy not taxed or regulated by the government (International Labour Organization, 2002). Because informal jobs do not contribute to tax revenues there are fewer government funds available for necessary social and economic programs such as education, housing, and infrastructure. There are many different types of jobs that would be classified as part of the informal economy. Some examples include small business enterprises such as street vendors or garbage collection for resale (Rogerson, Christian M, 1996). The informal economy plays a large role in employing Namibians and cannot be overlooked.

2.2 Informal Waste Collection

In the informal job sector of Windhoek, trash collection is one of the major sectors. People who engage in scavenging trash for a living are known as informal waste collectors. Informal waste collectors search for materials such as plastics, glass, cardboard, paper, and metals that they can use to make something more useful or resell for a profit. Typically, the informal sector of waste collection consists of either individuals or small groups that actively collect the waste and others who are the buyers or recyclers (Katusiimeh, 2013). Scavenging for recyclable materials as a means for income is prevalent in many countries worldwide.

In developing countries around the world, estimates show that 1 to 2 percent of the populations of large cities are supported by the garbage produced by the upper 10 to 20 percent of the population (Marques and Hogland, 2000). Informal waste collectors can actually have a very positive impact on the recycling systems in cities. By removing recyclable materials from

dumps or landfills, the waste pickers are increasing the lifetime of these landfills. Also by recycling materials that were not removed in the earlier steps of the waste collection process, the informal waste collectors make a contribution to reducing natural resources consumption (Moreno-Sanchez, 2006). These same positive outcomes influenced by informal waste collectors are demonstrated in Windhoek.

2.2.1 Informal Waste Collection in Windhoek

Informal waste collection takes a variety of forms in Windhoek. Some informal collectors travel to the city's residential areas and dig through garbage cans or bags placed on the streets. Until recently, most informal collectors utilized landfills around the city of Windhoek for waste collection. Until 2011, approximately 600 people resided in the Kupferberg Landfill, the main landfill used for both general and hazardous wastes, and scavenged through the refuse as a means of supporting themselves and their families (Hasheela, 2009). The residents collected scrap metal such as copper wire, materials to make baskets and furniture, or sometimes even discarded food to eat or resell (Gaoes, 2013).

The number of informal waste collectors operating at Kupferberg was brought into the public eye in 2011 when it became evident that they were severely disrupting the operations at the landfill and as a result, the federal government of Namibia intervened (Konjore, 2013). Over the next six months informal waste collectors were forced out and security around the landfill was strengthened. Today in 2014, some 20 informal waste collectors are permitted to operate in Kupferberg.

As is the case globally, the informal waste collectors have the potential to play a significant role in the overall waste collection and recycling systems. A study performed on Windhoek for a dissertation thesis showed that 45 percent of the materials sent to the Kupferberg

Landfill were actually recyclable materials, as shown in Figure 5 (Hasheela, 2009). Alone this is a staggering number which shows that there is much improvement needed for Windhoek's recycling systems; however, the informal waste collectors are able to reduce these numbers by taking and reselling the recyclable materials they find. In spite of their large contributions to recycling in Windhoek, informal waste pickers face many challenges.

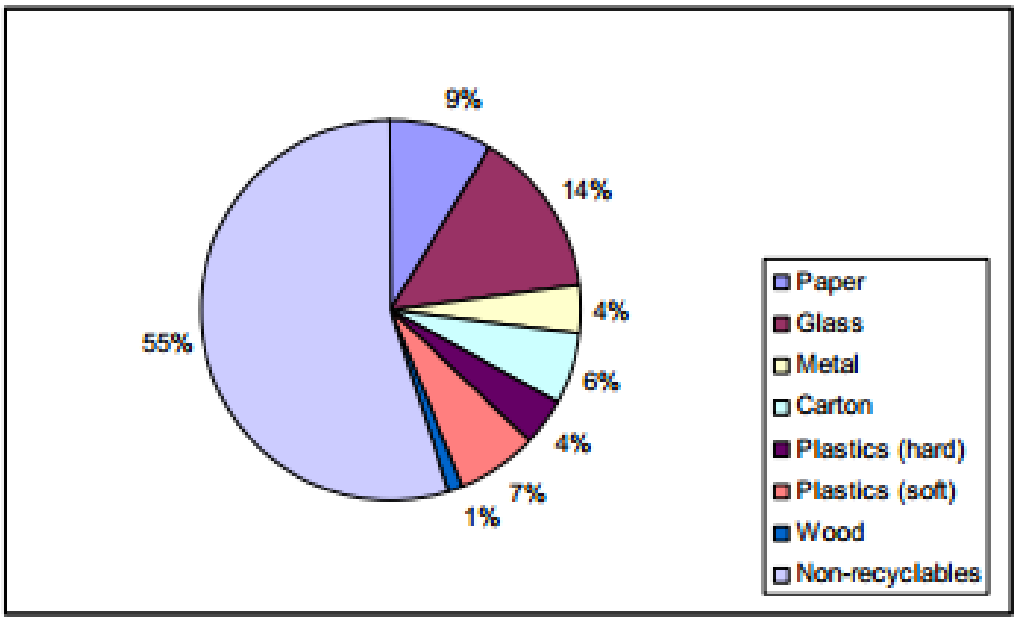

Figure 5: Breakdown of waste brought to the Kupferberg Landfill, chart: Hasheela, 2009

2.2.2 Problems with Informal Waste Collection

Although many people resort to waste collecting as a means of income, it is both physically demanding and unhygienic work. Typically, informal waste collectors do not have access to proper equipment for digging through trash or places for storage of the materials they collect. Consequently, they resort to sifting through garbage with sticks, simple hooks, or their bare hands and then carry what they find in heavy bags (Moreno-Sanchez, 2006). Digging through garbage in this manner exposes the informal waste collectors to numerous health and environmental hazards, such as bacterial contaminants, harmful chemicals, and ergonomic issues, which a regulated industry would prevent.

In addition to the physical and health risks, many feel that informal waste collecting is demeaning work. The general public often discriminates against informal waste pickers due to the filthy and belittling nature of their work (Moreno-Sanchez, 2006). Being discriminated against can be stressful which can affect a person's psychological wellbeing. Informal waste picker's psychological wellbeing may also be adversely affected by their lack of economic security and access to normal social services (Moreno-Sanchez, 2006). People who work as informal waste pickers do not have a stable income which leads to much uncertainty in their day to day lives. Overall, it is important to help informal waste collectors find more stable occupations to make their lives more comfortable and healthy.

2.3 Formal Waste Management

Municipal solid waste (MSW) is defined by the Environmental Protection Agency as everyday items that are used and thrown away. Management of MSW is a major challenge throughout the world and must be well organized to prevent problems such as health risks and environmental damage (Rav and Unnisa, 2013). There is a traditional hierarchy of waste management for the disposal of MSW, as shown in Figure 6. This method attempts to maximize recycling and energy conservation which ultimately decreases waste buildup (Rav and Unnisa, 2013). Namibia's MSW management is similar to the traditional hierarchy of waste management used throughout the world with the exception of the recovery phase. Namibia does not burn any waste for energy recovery. This is primarily attributed to the absence of proper factories capable of recovering energy through burning waste (Hasheela, 2009). The inability to burn waste to generate energy results in only a slight difference in the amount of waste that reaches the landfill as many of the materials that could be burned are repurposed instead.

Figure 6: Hierarchy of waste Management, chart: DC Waste Management Ltd, 2012

2.3.1 Formal Waste Management in Windhoek

Household waste in Windhoek is managed by the City of Windhoek and supplemented by private waste management companies. The city utilizes a green wheelie bin system where residents are provided with a bin for general waste that they collect every week. The only regions of Windhoek that are not included in this system are the informal settlements. The residents of informal settlements instead rely on black bags that are offered for general waste. The majority of the waste collected by the city of Windhoek is brought to the Kupferberg Landfill. See Appendix A for a map of the City of Windhoek's landfills and waste collection schedule.

2.3.2 Recycling in Windhoek

Unlike general waste collection, recycling in Windhoek is privatized and managed by several different companies. One of the major partners of the City of Windhoek for recycling is Rent-A-Drum. Rent-A-Drum began in 1989 as a waste management company which charged for waste collection from both businesses and residences. Rent-A-Drum has since expanded to the collection of recyclables and has grown into the largest enterprise of its kind in Namibia (Rent-A-Drum, 2013). Rent-A-Drum began recycling using a clear bag system in conjunction with the

normal household waste collection. Households use the clear bags to separate out recyclables from their waste stream. The bags are then placed out with the garbage bin provided to residents by the city and are collected separately by Rent-A-Drum without charge. Rent-A-Drum brings the clear bags to their Material Recovery Facility (MRF), where the recyclables are separated and packaged to be brought to the reprocessing plants (Rent-A-Drum, 2013).

Rent-A-Drum's recycling system works with a variety of materials that can be reprocessed back into raw materials. Glass is separated by color and smashed into smaller pieces to be easily moved to a processing plant in South Africa. Plastics are shredded or compacted and sent to both Namibian and South African processing plants to be reused. Paper and cardboard are handled in a similar fashion to plastic and are reprocessed into pulp and paper in South Africa. Aluminum cans are crushed, baled, and ultimately exported for reprocessing (Magen, 2010). Although Windhoek has a local landfill and is able to recycle many of the materials through Rent-A-Drum, there are still significant drawbacks to the current MSW management system.

2.3.3 Drawbacks on the Current Formal System

The MSW management system in Windhoek is currently not cost effective or environmentally friendly. First of all, there are limited resources in Namibia for dealing with the reprocessing of recyclable materials. Once Rent-A-Drum has sorted the recyclables, the nearest recycling processing plants to Windhoek for the majority of recyclable materials are located just outside of Cape Town, South Africa (Hasheela, 2009). This means that most recyclable materials that are sent to a processing plant must be driven over 1,500 kilometers. The costs of fuel and the environmental impact of fuel emissions from driving such a great distance are very high. Another drawback is the fuel costs and emissions from collecting waste and recyclables at households. Driving along these routes through all the neighborhoods in Windhoek is wasteful of

fossil fuels for the city and Rent-A-Drum. Although there are some strong disadvantages to the current formal collection system, the waste is still managed and most of it is collected in some way.

2.4 Integration of formal and informal waste collection

The formal and informal waste collection programs each have their own strengths and weaknesses. A unified system that integrates the two waste collection systems could theoretically be more cost effective and environmentally friendly than the current formal system, as well as create jobs for the informal waste collectors.

2.4.1 Role of informal collection in a formal system

Instances of combining of informal and formal waste collection occur in other areas of the world. In the city of Kampala, Uganda, the solid waste management has distinct sectors, the formal and the informal (Katusiimeh, 2013). The formal sector is a combination of public services with private companies collecting waste in designated containers. However, the formal collectors are not usually capable of going door to door to collect the waste at the poorer households on the outskirts of the city. Informal waste collectors take advantage of this opportunity and rent their services to these households for the removal of their waste.

A similar situation occurs in the city of Managua, the capital of Nicaragua (Campos, 2013). Like Uganda, the formal municipal waste collection does not adequately serve the informal settlements which leads to the inability of many residents to properly dispose of their waste. Similar to Windhoek, Managua is comprised of many informal settlements. Informal collectors see this as an opportunity for income from residents willing to pay to have their waste collected. They serve the communities using carts to collect waste. Informal waste collection

systems tend to arise as the result of formal waste collection services not meeting the needs to the people.

2.4.2 Informal waste collection becoming formal

In Nicaragua, the informal collectors see the inability of the formal waste companies as an opportunity for income and have served the communities using carts to collect waste. In one of the city's districts, Manos Unidas, a cooperative of 18 cart men formed to collect waste (Campos, 2013). Initially met with backlash from the police and formal waste collectors, the cart men slowly transitioned to a formal collection agency. With support from a local NGO, the cart-men were trained in basic business and accounting and the city began signing temporary licenses with them to collect waste. The target communities were initially hesitant about the program. Slowly, the informal waste collection programs which were developed out of need have become fundamental components to waste collection in impoverished societies.

Figure 7: Cart collection of waste in Nicaragua, photo: Campos, 2013

2.4.3 Bicycles as complements to current technologies

One of the positive results behind the success of informal waste collectors is the creativity that emerges. Because the informal collectors often face obstacles that formal waste collectors do not have to contend with, creative solutions can develop which can complement some formal waste collection techniques. This creativity can even be found in first world countries where people with different social and environmental agendas often disagree with the status quo method of formal waste collection.

In countries like the United States, determined entrepreneurs can turn their ideas into a business. Twelve years ago, a cooperative called Pedal People was started in Northampton, Massachusetts (Pedal People, 2014). Pedal People was created by individuals that wanted to experiment with a bicycle waste collection system. Starting in the winter, to see how feasible it was in the most extreme New England weather, they began collecting waste, recyclables, and compost from local homes in the area. The operation received support from local officials and with sixteen part-time employees it now serves approximately 500 households. Pedal People is also in charge of emptying the public waste containers for the town. Each cyclist can haul approximately 300 pounds of waste on a single trailer load, equivalent to between 6 and 8 households. One of the keys to their success is that they are operated as a cooperative, meaning each employee has a say in the operation, and this encourages them to work together and avoid conflict (Woodring, 2014).

Figure 8: Pedal People company in Northampton, Massachusetts, photo: Pedal People, 2013

The advantage of bicycles is recognized throughout the world. In 2005, Aaron Wieler together with Michael Linke started a program of bicycle empowerment in Namibia (Wieler, 2014). The goal was to make ambulances that could be pulled by bicycles to increase access to health care for rural Namibians. Today, the bicycle ambulance is operational in several rural communities around Windhoek. As a result of the use of bicycles, communities that could not afford traditional ambulances now had a reliable vehicle for emergency transport. This is just another example of bicycles supplementing current technologies.

2.5 Summary

To reiterate the main points of this chapter, unemployment is a major issue worldwide that contributes to poverty and poor living circumstances. With too few jobs available in Namibia, more people try to make a living in the informal economy, many as informal waste collectors. The work is demanding, unsafe, piece rate and poorly paid. The formal waste collection system in Windhoek also has many drawbacks including high emissions from their recycling trucks. For these reasons, the School of Natural Resources and Tourism at the Polytechnic of Namibia has asked us to help explore models for an integrated formal and informal bicycle recycling pickup program. This program has the potential to reduce both costs

and emissions from fuel used by collection trucks and to create new job opportunities in Windhoek. In the following chapter we will detail the methods we will use to reduce unemployment and decrease the environmental impact of formal sector waste collection.

3.0 Methodology

The goal of this project was to explore a model for integrating the informal waste collectors into the formal waste collection system, thus reducing unemployment and improving the overall waste management system in Windhoek. The project was performed in conjunction with students from the Polytechnic of Namibia, The City of Windhoek, and Rent-A-Drum. To realize our goal, we broke down the project into the following objectives:

1. Assess the current waste management system in Windhoek,
2. identify the current practices of informal and formal waste collectors,
3. develop a transportation prototype for collecting waste,
4. design and operate a pilot program implementing the prototype,
5. analyze the social acceptability of the pilot program,
6. and determine the economic and environmental benefits of the pilot program.

The subsequent sections detail the methods we used to accomplish these objectives as well as justifications for the selection of each method.

3.1 Objective 1. Assess the Current Waste Management System in Windhoek

In order to begin work on formal and informal waste collection integration, we first began by assessing the current waste management systems in Windhoek. Without a solid understanding of the current system it would be nearly impossible to make improvements. To complete our first objective, we conducted semi-structured interviews with several different parties.

3.1.1 Interviewing related waste management organizations

We first interviewed employees of Windhoek's Solid Waste Management Division and other organizations related to recycling and solid waste management in Namibia. Speaking with

these groups gave us a broader perspective on Windhoek's policies and procedures for waste management. Specifically, we learned about Windhoek's landfill operations, collection and transportation of waste, and the interactions of the city's departments with the other waste management organizations.

We began by meeting with John Pallett, an employee of South African Institute of Environmental Assessment as well as member of the Recycle Namibia Forum. We briefly discussed our project and he suggested several contacts, including the Recycle Namibia Forum coordinator, who would be important for us to meet to advance our project past the planning stages.

Our first step in understanding solid waste management in Windhoek was to meet with key informants around the landfill site and further our knowledge of their operations. We met with Dieter Tolke, a site engineer in charge of the Kupferberg Landfill. He led us on a tour of the landfill during which we interviewed him about both landfill operations and general recycling processes in Windhoek. We also discussed how the informal waste collectors currently operate in the landfill. Following this interview we also interviewed Stellio Tsauseb, the section engineer for all of the landfills around Windhoek. Our conversations with Stellio were directed towards background information on the overall landfill management and the city's relationship with Rent-A-Drum. In addition, we discussed the feasibility of utilizing city owned satellite landfill sites and transfer stations during our waste collection program.

After addressing the landfill management we met with other sections of Windhoek's Solid Waste Management Division. To learn more about the current state of recycling awareness in Windhoek, we interviewed Miriam Omonighbehin from Solid Waste Management Education and Marketing. She told us about many of the difficulties that both the City of Windhoek and

Rent-A-Drum face in relation to increasing both the rate of recycling and proper waste disposal. Additionally, we discussed the marketing relationship between Rent-A-Drum and the City of Windhoek for their clear bag system.

We then interviewed Ms. Miya Chipeio from the Division of Licensing and Special Projects about past recycling and academic projects sponsored by the city and the challenges that they have faced. We also discussed the logistics of starting up a pilot study for the project and planned a follow up meeting, during which we finalized the pilot study details.

The last people we interviewed were Anita Witt, the Coordinator of the Recycle Namibia Forum, and Gerrit Van Schalkwyk, head of the Namibia Cycling Federation. Both of these interviews were focused on raising awareness of our project and soliciting advice about the feasibility of attempting to start up a bicycle waste collection program. During these interviews we also discussed details of continuing the project on a longer time scale. See the questions and other details of the interviews in Appendices A through J.

3.1.2 Interviewing Rent-A-Drum

Our second key interview was with Rent-A-Drum. This was important because Rent-A-Drum plays a significant role in the recycling system in Windhoek and we hoped to establish a working knowledge of their recycling practices before moving forward toward our goal. We first met Rohan Louw, a business developer at Rent-A-Drum's sorting facility. Rohan guided our team on a tour of their facility and discussed their operations. We followed up this tour with a short interview to answer questions related to collection of recyclables and finances. Upon completion of this objective, we had enough information to begin working with the parties directly involved with our project. See the questions and other details of the interviews in Appendix F.

3.2 Objective 2. Identify Current Practices of Informal and Formal Waste Collectors

With the aim to create jobs for informal waste collectors in the formal sector, we also had to identify the current practices of both the informal and the formal waste collectors. We were looking to understand their operations, the organization of their work, and the extent to which the informal waste collectors would see our project as an opportunity to enhance their jobs. Having knowledge of the lives and opinions of informal and formal waste collectors played a crucial role in developing a program to meet their needs. We utilized two different methods to meet this objective which we detail in the following sections.

3.2.1 Observing Formal and Informal Waste Collectors

To begin identifying the current practices of informal and formal waste collectors we employed participant observation for both informal and formal waste collectors. We first observed informal waste collectors on our tour of the Kupferberg Landfill. There were approximately ten workers collecting recyclables in trash bags after each truck disposed of their contents. We met with Wilka Stefanus, the coordinator of the informal waste collectors, and arranged an interview to discuss their work. We observed the formal waste collectors both driving trucks and sorting recyclables at the Rent-A-Drum facility. We got a better understanding of the operations of the truck drivers by speaking with a group of Rent-A-Drum truck operators while observing and enquiring about their work.

3.2.2 Interviewing Informal Waste Collectors

To further identify the current practices of informal waste collectors we interviewed Stefanus, as well as two other members of her cooperative. For the interviews we were accompanied by three translators, Martin Shivute, Matheus Ruusa, and Allison Anderson

brought along three translators since the three informal waste collectors primarily spoke Oshiwambo. We divided into two groups; one group spoke with Stefanus while the other met with the two other informal waste collectors. During these interviews we asked, were you around when the informal waste pickers were removed from the landfill? We elaborated on this question to assess the extent to which they were affected by this removal of informal waste collectors. We also talked about the regulated recyclable collection in Kupferberg that Stefanus facilitates to improve our understanding of their operations and the challenges they encounter. Lastly, we spoke about our bicycle waste collection to gauge if they would have any suggestions or opinions about the project. See the questions and other details of the interviews in Appendix J.

3.2.3 Interviewing Formal Waste Collectors

To identify more of the current practices of the formal waste collectors we briefly interviewed a Rent-A-Drum truck collector as he drove us along his route. During the interview with the truck collector we discussed his typical routes and asked, do any informal waste collectors ever cause you trouble or interfere with your work? We also attempted to enquire about the number of trips they make back and forth to Rent-A-Drum each day but were unable to obtain a clear answer. With this information, as well as the information we obtained from our other methods, we were able to move forward with designing a bicycle attachment for the pilot program. See the questions and other details of the interviews in Appendix M.

3.3 Objective 3. Develop a Transportation Prototype for Collecting Waste

In order for the informal waste pickers to move large amounts of recyclable material in a timely manner, we designed and prototyped a bicycle with a cart attachment. We began by researching and contacting companies about designs and used the information to design and build our own attachment.

3.3.1 Vehicle Design

Our research began by contacting Pedal People of Northampton MA, since their method of bicycle waste collection has worked for the past twelve years. They connected us to Michael Linke, another bicycle enthusiast, who created the Bicycle Empowerment Network of Namibia (BEN). Once we arrived in Namibia, we met with Linke to talk to him about a project he started in 2004. BEN Namibia worked on a bicycle ambulance for the rural villages in Africa. The ambulance was made of steel frame that can hold a stretcher that can be pulled by a standard mountain bicycle as shown in part in Figure 9 below. Linke lent us one of his ambulances and mountain bicycles on which we based our design.

Figure 9: Bicycle ambulance from BEN Namibia

Linke's design has been updated and changed over the past 10 years, and has become a very sturdy, easy to manufacture design that is also cost efficient. By using the same tires as the mountain bicycle, it also has very easily replaceable parts. His team also put a large amount of work into making a simplistic, yet very maneuverable universal joint that connects the trailer to the seat post.

From his design, we were able to diverge and create our own modifications to better suit waste collection. We met with two mechanical engineering fourth year students from the

Polytechnic of Namibia, Adelino Paulo and Frans Hanghome, who helped us determine what parameters, such as shape, size, and construction materials, were essential to the design of the cart as well as ideas about the design. After this discussion with the students we moved forward with the design by drafting our ideas in SolidWorks. With a concrete plan for the design of the bicycle in place we moved forward with the manufacturing of the bicycle cart. Pictures of the SolidWorks drawing can be found in Appendix V.

3.3.2 Vehicle Manufacturing

Once we finalized our design, we manufactured the prototype with the help of Wisdom Nyagormey in the Polytechnic's fabrication laboratory. We purchased material from a local building supply company. In the fabrication lab, we began by cutting pipes and using a hydraulic pipe-bender to shape them to fit out design. Once we properly shaped all of the steel pipes, we used an oxy-acetylene welder to join the steel pipes to make our frame. With the frame completed, we purchased a custom-made canvas bag to fit inside our metal frame from the Outdoor and Canvas Center. We secured the bag inside the frame with nylon rope which completed the manufacturing of our cart. Lastly, we built our own universal joint based on the bicycle ambulance's joint which we used to fasten the cart to our bicycle. The specifics of our cart design and manufacturing process are discussed in detail in Chapter 4 and Appendix O.

3.4 Objective 4. Design a Pilot Program Implementing the Prototype

In order to demonstrate the effectiveness of bicycle-based collection in the formal system, we designed a pilot program. The pilot program involved two separate operations. We first collected recyclables in a neighborhood where residents actively participate in Rent-A-Drum's clear bag system. We then operated in a neighborhood where the clear bags are not present and sorted recyclables for the residential waste bins. For the pilot programs we were able

to incorporate an informal waste collector from the landfill as a volunteer. The two operations of the pilot program were essential for showing the benefits of bicycle waste collection in the formal system.

3.4.1 Research and Design of the Program

Rohan Louw, from Rent-A-Drum, gave us information on the neighborhoods that their clear bag recycling system is used in, which included data about the amount of waste collected each week from the regions of Windhoek. We also spoke with Robert Reithmuller, a professor in the Polytechnic's department of land management. He was able to give us information on income distribution, population densities, and motor vehicle traffic in the areas of Windhoek where the design was to be implemented.

Once we collected necessary background data, we moved forward with the pilot route design. The first pilot test involved working with Rent-A-Drum and using the bicycle cart to collect their clear bags. Our intent was to test if the bicycle cart could be used to supplement the existing system of recyclable collection. The second test route utilized at-the-source recycling by having our volunteer sort through the trash bins supplied by the city and remove recyclables. This pilot trial was designed to determine if the bicycles could make at-the-source collection of recyclables a feasible job. Based on the information we gained from our previous interviews we decided the regions of Windhoek in which we operated. See the questions and other details of the interviews in Appendix F. The specifics of our route design process are discussed in detail in Chapter 4.

3.4.2 Implementing the Pilot Program

Upon completing the manufacturing of our prototype and designing the pilot routes, we then implemented the pilot program to collect data and test all parameters of the designs. We

worked with Stefanus to find an informal waste collector, Helmut Uriab, who was willing to participate in both pilot routes of our pilot program. Because of the limited time period for our research we only ran each pilot route for one day. For each operation we gathered data on the recyclables produced by households, the feasibility of bicycle collection, the mechanics of the bicycle cart, and solicited Helmut's views of the process. For the run with Rent-A-Drum, Helmut biked along a few streets at a time while collecting the clear bags of recyclables and loading them into the bin attachment. After collecting the waste at each house along the route, Helmut then transported the bags to a nearby drop-off point. The drop-off point was a Rent-A-Drum recycling station. At the drop-off point we had a group consisting of ourselves and our sponsor, Clarence Ntesa, sorting the recyclables into bottles, cans, plastics, paper, and cardboard. All the recyclables were later picked up by Rent-A-Drum and brought to their sorting facility. We operated the second run in a similar fashion by utilizing several streets around one drop-off point, but instead of grabbing the bags of recyclables, Helmut sorted through the trash bins in search of recyclables. This process was meant to reflect the work that he performs at the Kupferberg Landfill of sorting recyclables out of the MSW stream. We calculated the amount of material Helmut brought in, its value, and the total costs of paying the volunteer commission and maintaining the vehicle in order to determine if this could be a reliable source of income.

3.5 Objective 5. Analyze the Social Acceptability of the Pilot Program

We identified two different groups of people who could experience social repercussions as a result of our project. These groups included the local residents whose houses were along the bicycle waste collector's route and the informal waste picker who was employed to collect the recyclables. We utilized a variety of methods to quantify the social consequences for each of these parties.

3.5.1 Interviewing Local Residents

It was necessary to determine the attitudes of the local residents towards the bicycle collection system because their cooperation would be instrumental to the success of the program. To begin these evaluations, we interviewed residents whom we passed in the streets while operating the pilot program. Owing to the time constraints, we were limited to speaking with eight residents. Through these interviews, we learned if the local residents were concerned with bicycle collection in lieu of truck collection. We chose to have unstructured conversations primarily because of our limited time and direct communication was the most effective method for receiving constructive feedback. See the questions and other details of the interviews in Appendix N.

3.5.2 Interviewing Our Volunteer Bicyclist

Determining the ways in which the pilot study affects the life of an informal waste picker was also critical to the project's success. At this point we had established a good working relationship with our pilot program volunteer, Helmut. After our pilot routes, we interviewed Helmut in order to assess the effectiveness of the routes. We were looking to determine if Helmut found the working conditions to be improved from those of the landfill. We also sought criticisms from Helmut on the organization or operation of the pilot route. From our interview, we were able to accurately compare his opinions about informal waste collection versus working as a bicycle waste collector. Unfortunately, we did not receive much input on improvements to make this job more appealing to others. With the social implications of the project analyzed through a variety of different perspectives, we moved forward to process the data to assess the practicality of bicycle recyclables collection. See the questions and other details of the interviews in Appendix L.

3.6 Objective 6. Determine the Economic and Environmental benefits of the Pilot Program

The sixth and final objective of our proposal was to determine the economic and environmental benefits of our proposed system. In order for our proposed system to be considered for implementation, the City of Windhoek and Rent-A-Drum had to be willing to make proposed changes. To show the economic benefits of the program, we perform a cost analysis on the recyclable materials collected during our two bicycle collection systems in order to demonstrate its value. For the environmental benefits of our program we analyzed the reduced diesel emissions from bicycle collection compared to truck collection to clearly show the city and Rent-A-Drum what positive environmental impact our program could create.

3.6.1 Economic Benefits

Once we had completed our pilot program we started analyzing the economic factors of the bicycle collection program. We began by assessing the total cost of manufacturing our bicycle cart. This was important in order to compare the upfront startup costs of our bicycle collection to investing in garbage trucks for collection. In addition, we briefly looked into the difference in maintenance costs and reduced costs from fuel consumption, but this was hard to quantify with limited information on Rent-A-Drum's operational costs.

We also looked into the monetary value of the recyclables that we collected. During the program we separated out the different recyclable materials and weighed them at the drop-off point. Using numbers that we obtained during our interview with Stefanus, we were able to determine how much Rent-A-Drum would pay for the quantities of recyclables collected. This was important for us to analyze if bicycle collection would be worthwhile for an informal waste

collector. Lastly, we analyzed potential methods for the remuneration of the bicyclist including payment by weight of recyclables or a monthly wage.

3.6.2 Environmental Benefit

In addition to the economic analysis, we also considered the environmental benefit of bicycle collection. For this we had to look at our two pilot routes separately. The first pilot route with Rent-A-Drum lessened the environmental impact from reduced fuel consumption. We assessed the potential fuel savings from bringing the bags of recyclables to a central location instead of the trucks driving from house to house. Again, we were limited in our ability to make specific calculations by our lack of information on Rent-A-Drum's operational costs. Our second program created a positive environmental benefit from reducing the amount of recyclable material reaching the landfill by removing them from the waste bins.

3.7 Obstacles

There were several obstacles that we confronted during the execution of our methods. One preliminary obstacle we encountered was a misunderstanding of the recycling systems and state of informal waste collectors in Windhoek. Some of the information from our initial research such as the extent of informal waste collecting in the landfill proved to be outdated and we were set back by a lack of current knowledge. As a result, we found ourselves having to spend more time interviewing key informants for our initial objectives. Another more significant obstacle we faced was a lack of financial information about Rent-A-Drum's operations. We originally wanted to compare bicycle cart collection with the costs of truck collection for Rent-A-Drum, but could not do so as the company's operation costs were proprietary.. Lastly, we faced a problem with the time constraints of our research limiting our data collection. For each of our pilot trials we were only able to operate once. This is not ideal for any form of research and has

limited the scope of our data. These were some of the most significant hindrances that we faced during our project. The next chapter details the construction of our bicycle cart and the design of our pilot route.

4.0 Manufacturing and Design

In this chapter we discuss our manufacturing process for the bicycle cart as well as the designs of the pilot programs.

4.1 Bicycle Cart Design and Manufacturing Process

This section covers the results of our bicycle prototype. We will first cover the specifics of our design process to detail how we decided on our final product. We then go over our material preparation for the manufacturing process. Lastly, we discuss our assembly process and show our final product.

4.1.1 Cart Design

In order to finalize the design process of our cart we met with two engineering students from the Polytechnic of Namibia, Adelino Paulo and Frans Hanghome. We made a design specifications table where we specified the functions of the cart, the objectives of our design, the constraints, and the free variables. The specifics are shown in Table 1 below.

Function	Objective	Constraints	Free Variables
Holding Recyclable Bags	Light	Width	Paneling Material
	Cost-Efficient	Height	Shape
	Maneuverable	Weight	
	Easy Manufacturing	Length	

Table 1: Design specifications

Once we narrowed down the essential factors to consider, we began detailing the specifics of our cart design. The first variable we considered was the material from which we built the bicycle cart. When choosing a material, we had to take into account cost, weight, and ease of manufacturing with respect to pipe bending and welding. We debated over a variety of materials for the frame of the design, but two of the most practical options that we found were aluminum and steel. Aluminum would be ideal for lowering the weight of the frame; however it

is more expensive and much more challenging to weld and bend than steel. We ultimately decided to build the cart out of steel due to its lower cost, high strength, and simplicity for welding.

In determining the dimensions of the cart, the first factor that we considered was the importance of total volume versus weight of the cart when full of recyclables. When designing the cart, we attempted to choose a volume that would be equivalent to the maximum quantity of recyclables that our cyclist would be capable of towing. For this purpose, we asked Rent-A-Drum for information on weight estimates for individual clear bags. We found that the average weight of the bags is 3.9 kg, the maximum weight was 7.75 kg, and the minimum weight of the bags was 2.75kg. We compared this information with information we gained from the Pedal People organization on the maximum towing capacity of their bicyclists, which was approximately 100 kg. This weight capacity was a main driving factor behind the dimensions of our cart.

We were also constrained by the cart's maneuverability as well as the traffic in the city. Since traffic in Windhoek was already raised as a concern for biking in the city, we decided that the width of the cart should not greatly exceed that of the bicycle to avoid bulkiness and difficulty sharing the road with cars. We also decided that the cart could not be excessively tall so the biker would have no problems with unloading the recyclables or rear visibility obstruction. We determined that the length of the cart would also have to be limited such that turning would not be difficult for the bicyclist. Our initial designed called for a trapezoidal prism, 3 m long at the top, 0.8 m wide, and 1 m tall. After considering the size of this design, we decided to decrease the dimensions and settled on a rectangular shape of width 0.8m, height of 0.8m and a

length of 1.9m. This design was easy to manufacture and gave us the maximum volume for our given dimensions.

For our design, we needed 25 mm diameter steel pipe for the frame of the cart as well as additional supports and one hex nut for the seat post attachment. We also acquired 5 mm thick by 40 mm wide steel angle bracket for the wheel attachments and rust proof spray paint. Lastly, we bought a custom made canvas bag from the Canvas and Outdoor Centre with the dimensions of 190 cm long by 80 cm wide and 80 cm tall with an open top to place inside the cart. The total cost of the cart came to N$2482.60 which was more expensive than our initial intent but not over our budget. The prices and amounts are specified in Table 2.

Item	Price (N$)	Quantity	Cost (N$)
Hex Nut 16mm	8.77	1	8.77
Round Pipe 25mm	82.26	5 X (6 m)	411.3
Angle Bracket Steel 5mm X 40mm	249.37	1 X (6 m)	249.37
Spray Paint	90.97	3	272.91
Canvas Bag	1026	1	1026
Nylon Rope: 30m	60	1	60
		Bike Sum	2028.35
		Vat 15%	2332.60
		Delivery	150
		Total	2482.60

Table 2: Prices and quantities of materials for the bicycle cart

4.1.2 Cart Manufacturing

Appendix N provides a step by step process for the cart manufacturing. We summarize the process in this section. We manufactured the cart in the fabrication lab of the science and technology building at the Polytechnic with the help of Wisdom Nyagormey, the head of the lab. We utilized a variety of different machines, such as a pipe bender, band saw, oxy-acetylene welder, angle grinder, mill, and drill press, some of which we were familiar with, but others we had to learn to operate throughout. We utilized these specific machines because they are readily available in most fabrication labs.

We began by cleaning and cutting all of the necessary pipes for the assembly using the angle grinder and band saw. We then used the pipe bender to properly shape the pipes for our rectangular cart top and base. With the pipes for the rectangular box prepared, we then began tack welding the pieces into one solid structure and then finalized the box by strengthening the welds and capping the open pipes.

Figure 10: Measuring a pipe for cutting with band saw

The next step was to create the wheel slots from angle bracket. We cut the pieces to size using the band saw, milled slots into the bracket, and welded them onto the bottom of the cart. We then welded on three additional pipes to the front of the cart for the connection to the bicycle. On the front of the connection pipe, we welded a hex nut for the attachment of the universal joint. With the frame of the cart manufacture, we secured the canvas bag to the structure using nylon rope. The final cart is shown in Figure 11 below.

Figure 11: Complete bicycle cart

During the entire manufacturing process we faced a variety of challenges. The most significant challenge we overcame was our lack of manufacturing experience. This inexperience led to imprecisions during pipe bending, cutting, and welding that caused the dimensions of our design to fluctuate from our initial parameters. Additionally, inexperience caused us to spend excess time correcting our mistakes in the lab. We were also limited in our ability to perform a stress analysis on our cart due to the lack of the proper computer software. This meant that we were unable to analyze if our design was leading to excess stress in certain areas of the cart.

4.2 Pilot Route Design

For our pilot program we performed two separate operations. First we ran a route with Rent-A-Drum collecting their clear bags with our bicycle cart. Then we performed an operation separate from Rent-A-Drum where we used the bicycle cart to sort out recyclables at-the-source from the green wheelie bins supplied by the city. Below we detail both routes separately including the specifics of the route as well as the information that led us to the design of the routes.

4.2.1 Rent-A-Drum Collection Route

We began by designing a bicycle route which was to supplement Rent-A-Drum's clear bag collection. This proved to be an initial challenge for our study. We found ourselves unable to convince Rent-A-Drum to work with us for this supplemental route. In spite of this uncertainty around the operation, we began the design of the route. During the last week of our time to perform the pilot route, we secured their permission through continually contacting a variety of Rent-A-Drum personnel.

The first parameter of our bicycle route was to determine the number of households that we would target with each run. To make this decision we referenced specific numbers that the Pedal People cooperative uses for their trash collection. During a typical operation, a single bicyclist is able to collect from 6-8 houses per run before they have collected their maximum weight of approximately 100 kg. Each collector usually fills their trailer 3 times in a 2 hour work day. Based on this information, for our operation we decided to target between 10 and 15 households per run with a total of 4 runs. We increased the number of households from Pedal People's estimates because the average weight of a clear bag is 3.87 kg and households typically have no more than two bags. Based on this, our cart would not come close to the Pedal People weight towing capacity with this number of households. In addition, collection of clear bags would be faster than strapping down the bins that Pedal People use so the full route would not exceed the 2 hour time frame. This is ideal for our piloting purposes since we would not want exhaustion to render the inexperienced bicyclist completely unable to perform the testing.

The next consideration of our design was the safety of the bicyclists. The foremost concern of every individual that we interviewed prior to our design was the bicycle safety in a city that lacks the proper infrastructure for cycling. We were given many recommendations about

how to lessen this safety issue for the bicyclist that we have taken into consideration for our pilot program. Firstly, we attempted to isolate our initial route as much as possible to residential neighborhoods and refrained from major roadways whenever possible. We also determined that it would be safer to begin operations in the early morning and end before peak traffic times in the afternoon, thus minimizing the number of cars that would be on the road during the collection.

The last factors that we analyzed were related to the specific region of Windhoek in which we were to perform our pilot trial. We first decided that it would be ideal to use an area where the clear bag system is well established. By operating in an area that utilizes the clear bag system we were able to gather a larger data sample for our analysis of the effectiveness of the bicycle cart prototype. From there we had to choose a location that had an area which we could utilize as a central drop off point. Lastly, it was recommended to us to select a route that Rent-A-Drum collects from later in the day; therefore, giving us ample time to collect and sort recyclables without interfering with Rent-A-Drum's normal operations. These factors led to our decision of using the area of Windhoek West around the Polytechnic. According to our numbers from Rent-A-Drum, Windhoek West does show some participation in the clear bag system. This also enabled us to use the loading dock area of the Polytechnic behind the Science and Technology Building as our centralized drop-off point where we could have a large area to analyze and separate the recyclables. Furthermore, Rent-A-Drum does not collect from this area until the afternoon, allowing us to operate independently without any obstructions for the morning hours.

We scheduled our pilot trial for Thursday the 24th April, 2014 with our collection beginning at 07:00. We planned the collection along four different routes:

1. The first route began at the front gates of the Polytechnic. The route followed Mozart Street onto Beethoven Street with a short detour onto Schubert Street. Beethoven Street led onto Wagner Street and the route ended at the drop-off point behind the Polytechnic Science and Technology Building. This route covered approximately 1.1 km.

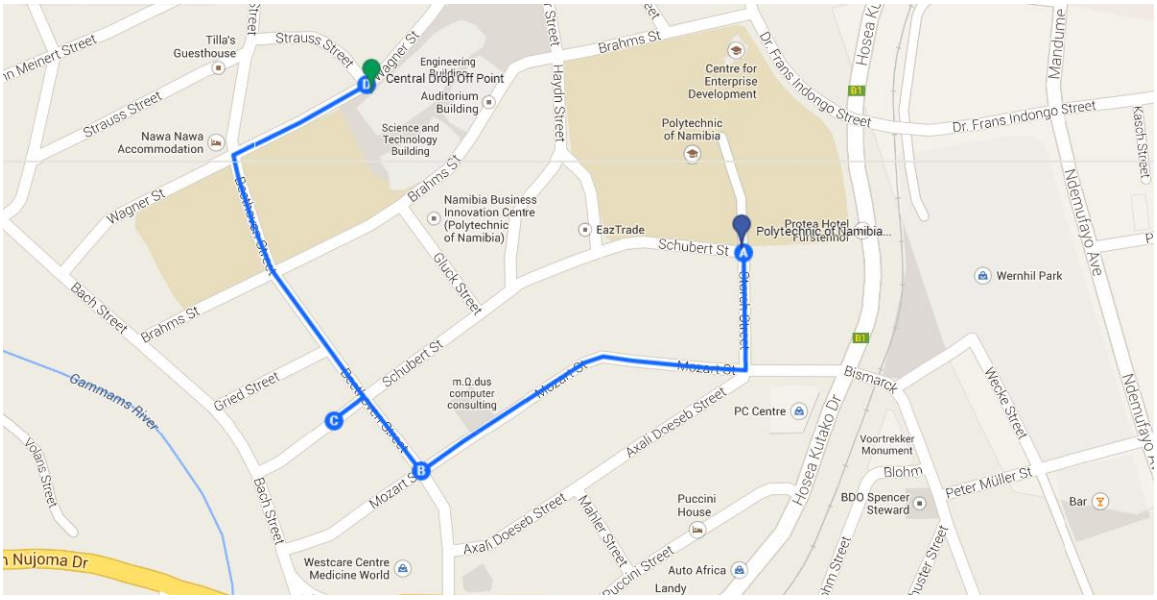

Figure 12: First route of the pilot trial

2. The second route began at the drop-off point. The route followed Wagner Street onto Verdi Street and then led on to John Meinert Street. After following John Meinert Street the route turned briefly onto Schonlein Street and then looped back to the drop-off point along Strauss Street. This route covered approximately 1.1 km.

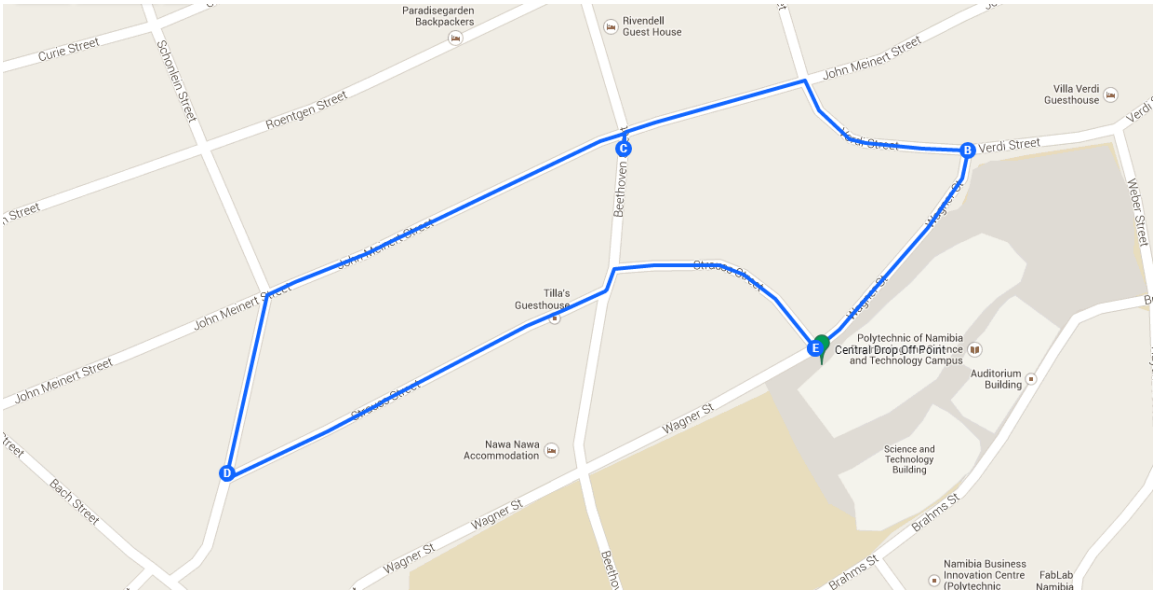

Figure 13: Second route of the pilot trial

3. The third route began at the drop-off point. The route followed Wagner Street onto Beethoven Street until the intersection of Roentgen Street. The route led to the end of Roentgen Street until it looped back to the drop-off point. This route covered approximately 1.7 km.

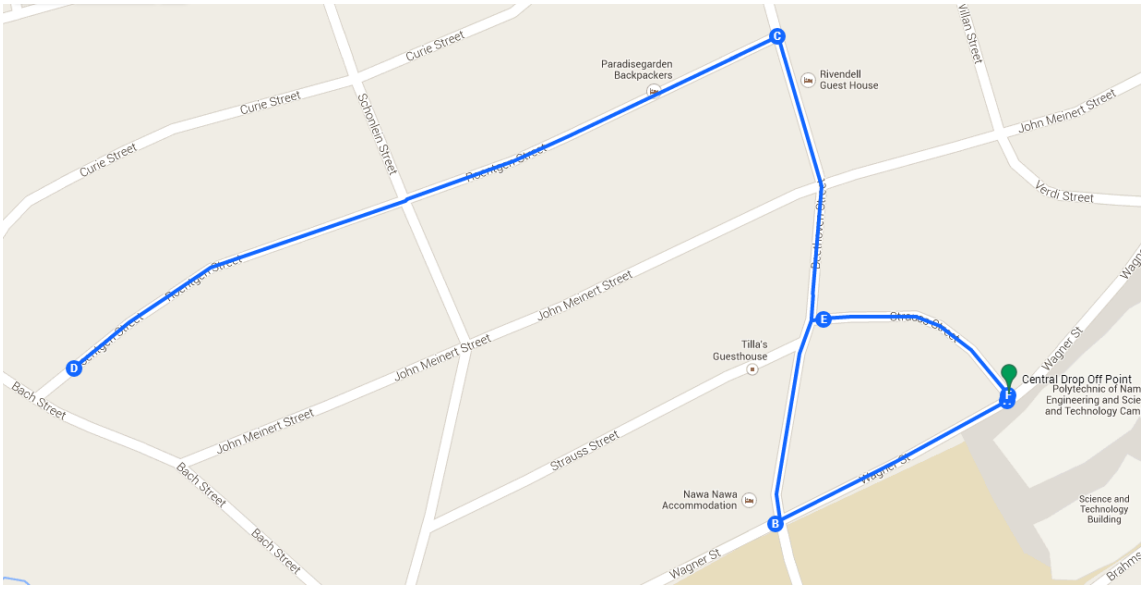

Figure 14: Third route of the pilot trial

4. The fourth route began at the of the drop-off point. The route followed Strauss Street onto Beethoven Street until the intersection of Simpson Street. From Simpson Street the route led onto Curie Street, up Bach Street, and then Best Street until the intersection of Jenner Street. The route followed Jenner Street onto Galen Street and looped back across Simpson Street towards the drop-off point. This route covered approximately 2.9 km.

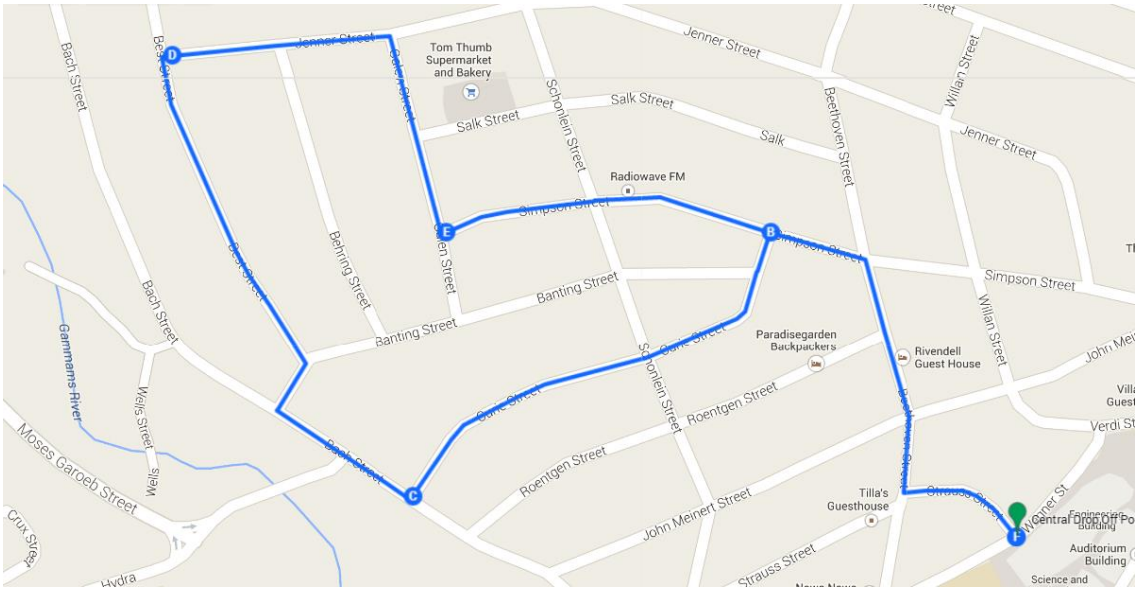

Figure 15: Fourth route of the pilot trial

These route selections were based on recommendations from a Rent-A-Drum truck operator on where we would find clear bags in Windhoek West. We did not specify the exact number of households at the beginning of the trial but continued with the estimate of 10 to 15 households per run. During the trial, two of our team members along with two Afrikaans translators from the Polytechnic, Elizabeth Pius and Laemi Antonius, walked along with our bicyclist volunteer, Helmut Uriab. More information on Helmut and his selection for our pilot study can be found in Chapter 5. We recorded the number of bags and time required to collect

from each household and observed the operation of the pilot program. Two of us, along with our sponsor, Clarence Ntesa, remained at the central drop off location to weigh and sort the recyclables as they were dropped off. Once the bicyclist completed the planned routes and we finished weighing and sorting recyclables, a Rent-A-Drum truck came to collect the recyclables from the central drop off point at the Polytechnic. Additional information we recorded during the pilot trial including comments we made about challenges and other observations can be found in Appendix S.

4.2.2 At-The-Source Collection Route

The second pilot route that we designed was operated separately from Rent-A-Drum. This operation focused on at-the-source recycling by removing recyclable material from the municipal green wheelie bins. Before performing the pilot operations, we had to gain permission to operate from the City of Windhoek. We submitted a formal request detailing the entire pilot route to Miya Chipeio from Licensing and Special Projects. Our request was expedited and approved during a follow up meeting with Chipeio.

When considering this pilot trial we had very similar parameters to consider from the first pilot trial. First we had to determine an appropriate number of households for which, using similar reasoning to that detailed above, we decided on 20 to 30. We increased this number from the previous trial based on the assumption that we would collect fewer recyclables from each bin than we would get in each clear bag. Another difference with this operation in respect to the number of households was the total number of runs. Because the at-the-source sorting would take significantly longer we decided that performing only 2 runs would be sufficient for our 2 hour time frame.

We again had to find an appropriate region of Windhoek in which we would operate our pilot trial; however, this trial had a different set of parameters than the previous. Namely, we were looking for a residential area in which Rent-A-Drum's clear bags did not have a strong presence. The data we received from Rent-A-Drum indicated that two of the areas where they collected the least amount of recyclables were Windhoek North and Rhino Park. We selected Windhoek North because of its proximity to the Polytechnic making transport of the bicycle cart to the route location easier.

We scheduled the pilot study on Monday the 28th of April, 2014 with the collection beginning at 05:00. The trial had to begin at the same time as The City of Windhoek collection to ensure that by the time they reached the neighborhoods that we tested in, we had finished our work. We planned the trial along two different streets: a loop along Stephenson Street and loop along Sauer Street.

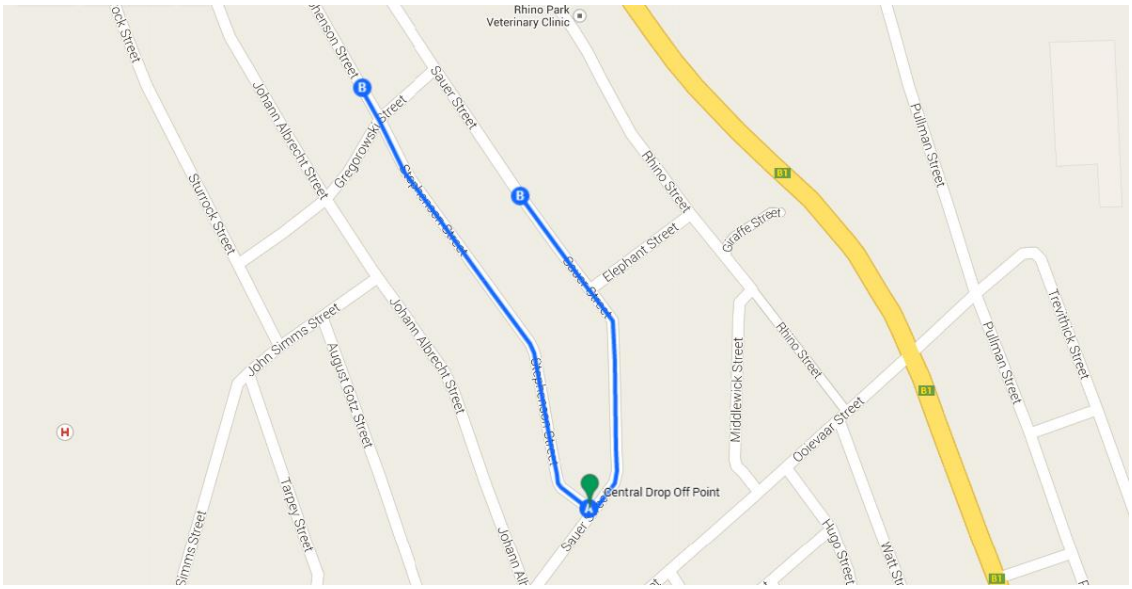

Figure 16: Second pilot trial routes

Originally, we planned to use the satellite landfill site between Windhoek North and Eros as our drop-off point. Upon arriving at the pilot location, we determined that this would be too

far away for the pilot program to be time effective. We instead utilized the street corner at the intersection of Stephenson and Sauer Streets as the central drop-off location. This location was not ideal for a permanent system but fit our purpose of a temporary sorting area. For the trial we worked with the same bicycle volunteer. We also repeated the same process of sending two people with the bicyclist and leaving two at the central location, both recording data on times and weights of recyclables. When the pilot study concluded we again sent all of the recyclables with Rent-A-Drum. Additional information we recorded during the pilot trial including comments we made about challenges and other observations can be found in Appendix T.

4.3 Summary

With the help of two engineering students at the Polytechnic, we modeled our bicycle cart after the design of the Bicycle Empowerment Network of Namibia's ambulance. We manufactured the bicycle cart in the fabrication lab of the Polytechnic. Meanwhile, using information that we gained from a variety of interviews we designed and established our pilot programs. We then implemented the pilot program with our informal waste collector volunteer, Helmut. The next chapter contains an analysis of the information we have gained through our research as well as the results of our pilot study.

5.0 Results and Analysis

In this chapter we will present and analyze the results of our research at the Polytechnic of Namibia. We begin by detailing our findings from our research on solid waste management and recycling in Windhoek. We follow up this section with the results of the pilot program and our relevant findings.

5.1 Waste Management and Recycling in Windhoek

This section covers our findings as well as additional background information we learned regarding the current waste management systems in Windhoek. The majority of these findings resulted from interviews we conducted with key informants during the initial stages of the project, including officials from Rent-A-Drum, and informal waste collectors working in the Kupferberg Landfill. We begin with a discussion of pertinent information we gathered on Rent-A-Drum's recycling operations. After this discussion we move into the findings about recycling awareness, the Kupferberg Landfill, and the informal waste collectors.

Rent-A-Drum Recycling Operations

Rent-A-Drum started in 1990 as a waste collection company for private businesses in Windhoek and has since expanded to other parts of Namibia. While the City of Windhoek pays contractors to collect waste from residential households, Rent-A-Drum collects waste from private businesses and residences that pay for additional waste bins. Private waste collection was Rent-A-Drum's only form of income prior to recycling which they began in 2002. The recycling operations have increased significantly since the establishment of the material recovery facility (MRF) and clear bag system.

Rent-A-Drum earns the bulk of its profits from collecting refuse from businesses and private households, but its recycling program is expanding. Every month, Rent-A-Drum

processes approximately 2,400 metric tons of recyclables. Despite the massive amounts of recyclables that they process and sell, virtually all of the recyclables need to be shipped to companies in the Cape Town region some 1500 kilometers away. Transport costs are significant and the company essentially breaks even from its recycling operations. According to Rohan Louw, the business coordinator at Rent-A-Drum, their facility is currently operating under capacity. He stated that the next goal of Rent-A-Drum's recycling operation is to increase their monthly intake to around 3,000 metric tons. If they achieve this amount, Rent-A-Drum will begin to see more significant profitability from their MRF.

Increasing Prevalence of Clear Bag System

From our interview with Louw, we learned that Rent-A-Drum is currently working to expand their clear bag recycling initiative to new areas of Windhoek. The clear bag initiative for household recyclable collection was started in 2010 along with the establishment of Rent-A-Drum's MRF. Since that time, Rent-A-Drum has been expanding the clear bag system in five phases targeting different regions of Windhoek. The first phase began in the higher income regions of Windhoek such as Klein Windhoek, Ludwigsdorf, and Eros Park. The phases ranged from higher income in phase one to lower-middle income regions such as Khomasdal, Rhino Park, and Windhoek North in phase five. Rent-A-Drum is currently in the fifth phase of their expansion and is working to promote recycling in the middle income neighborhoods where it has not yet caught hold. In each new region, Rent-A-Drum began by dropping an information packet with two free clear bags at every household. As of now, Rent-A-Drum has no interest in expanding its clear bag system to the lower income areas such as Katutura and the informal settlements. Katutura is not suited for Rent-A-Drum due to the absence of paved roads in many sections making truck collection difficult. In addition, there is a lack of solid waste management

and recycling education in Katutura. Next we move into our findings beginning with recycling education in Windhoek.

Finding 1: Lack of recycling education and limited recycling awareness are greatly hindering the expansion of recycling in Windhoek

Limited awareness of the benefits of recycling and the lack of recycling education are the main factors inhibiting the spread of recycling in Windhoek. From our interview with Rohan Louw, we discovered that recycling did not show much growth in Namibia until 2010, when Rent-A-Drum built their MRF. Since then, Rent-A-Drum has been the driving force behind increasing recycling activities, but recycling is still in its infancy stages after four years.

From our various interviews with both Rent-A-Drum personnel as well as City of Windhoek officials, we found that, in general, recycling has taken root in the higher income households, is still developing in the middle income households, and is almost non-existent in the low income households. As mentioned earlier, higher income regions of Windhoek were targeted in the initial phases of Rent-A-Drum's clear bag system. There were two main reasons for this decision. First, on average the higher income households generate larger quantities of waste; therefore, there is more recyclable material for collection. Secondly, Rent-A-Drum saw that these households were more predisposed to positive recycling habits. This can be clearly seen in Figure 17 below where the highest income regions shown in phase one as well as Pionierspark and Olympia show a much larger participation in the clear bag system.

RENT-A-DRUM
The Leading Organization in Waste Management

CLEAR BAG COLLECTION STATISTICS "PHASE 1,2,3,4&5"26 January 14- 25 Febuary 4 **Mon,Tues&Thursdays**

Phase	Area	Total Bags Week 1	Total Bags Week 2	Total Bags Week 3	Total Bags Week 4	Total Bags Week 5	Total KG Week 1	Total KG Week 2	Total KG Week 3	Total KG Week 4	Total KG Week 5	Total Bags per month	Total KG weight per month
One	Eros Park & Klein Windhoek	870	883	762	816	884	4520	3,480	3140	2900	3279	4,215	17,319
One	Klein Windhoek & Ludwigsdorf	850	907	1033	860	955	1660	3,400	3140	1892	3120	4,605	13,212
One	Klein Windhoek & Avis	465	872	608	134	542	2455	3017	2407	2506	2455	2,621	12,840
One	Part/Suidhof	549	560	493	574	575	2420	2,335	2180	2700	2260	2,751	11,895
Two	Suiderhof	231	202	193	207	206	836	1500	598	842	672	1,039	4,448
Two	Olympia & Auasblick	110	862	867	887	873	1030	3180	3560	3040	2900	3,599	13,710
Two	Kleine Kuppe	396	412	418	386	360	1,460	1698	1463	1497	1425	1,972	7,543
Two	Cimbebasia	139	128	160	108	195	508	954	496	440	636	730	3,034
Three	Academia	209	270	265	249	200	756	2006	856	1018	652	1,193	5,288
Three	Pionierspark	300	660	767	610	605	2,810	2760	2180	2560	2380	2,942	12,690
Three	Hochlandpark	244	214	212	247	240	900	882	777	958	955	1,157	4,472
Four	Pionierspark Extension 1	184	200	250	215	195	730	996	663	1270	726	1044	4385
Four	Tauben Glenn	148	158	156	165	158	387	395	404	408	575	785	2169
Four	Rocky Crest	15	36	65	43	60	60	352	578	268	218	219	1476
Four	Dorado Park	156	194	216	196	386	1,119	514	540	413	668	1148	3,254
Four	Windhoek West	222	216	189	212	212	585	536	490	523	772	1051	2906
Five	Central Khomasdal	117	85	134	123	111	466	424	357	726	414	570	2387
Five	Northern Khomasdal	6	9	9	5	0	24	88	82	31	0	29	225
Five	Southern Khomasdal	156	149	164	148	149	408	369	426	366	531	766	2100
Five	Otjomuise	196	168	100	154	156	1401	446	260	325	272	774	2704
Six	Windhoek North	8	0	4	6	5	21	0	15	18	22	23	76
Six	Rhino Park	0	0	3	0	0	0	0	18	0	0	3	18
Six	Areas												
One	Total:	2,734	3,222	2,896	2,384	2,956	11,055	####	####	9,998	11,114	14,192	55,266
Two	Total:	876	1,604	1,638	1,588	1,634	3,834	7,332	6,117	5,819	5,633	7,340	28,735
Three	Total:	753	1,144	1,244	1,106	1,045	4,466	5,648	3,813	4,536	3,987	5,292	22,450
Four	Total:	725	804	876	831	1,011	2,881	2,793	2,675	2,882	2,959	4,247	14,190
Five	Total:	475	411	407	430	416	2,299	1,327	1,125	1,448	1,217	2,139	7,416
Six	Total:	8	0	4	6	5	21	0	15	18	22	23	76
								GRAND TOTAL				33,233	128,133
								PREVIOUS TOTAL				26615	105871

Figure 17: Rent-A-Drum clear bag collection statistics

Miya Chipeio, from the City of Windhoek Special Programs and Licensing Division, informed us in our interview that all middle income households have been brought into the clear bag system; however the lack of recycling seen in several of these regions is due to the lack of awareness regarding recycling. Louw informed us that Rent-A-Drum is currently attempting for a second time to promote the clear bag system in Rhino Park and Windhoek North, two lower middle income regions, where it previously was unsuccessful. From our interview, we ascertained Rent-A-Drum redistributed their clear bag packages to encourage their recycling initiative.

We also confirmed this lack of awareness related to recycling when we saw the recycling bin stationed outside the Katutura neighborhood at the Physically Active Youth center. As shown in Figure 18 below, there were four bins: paper, plastic, glass and metal; yet we noticed that all

four bins had a mix of general waste in them with no attempt to recycle from the local residents. We have seen this disregard for standard recycling receptacles throughout Windhoek.

Figure 18: Rent-A-Drum recyclable receptacle with unsorted general waste

In addition, we found that both the City of Windhoek and Rent-A-Drum are working to spread awareness about recycling in order to increase the amount of recycling done at the household level. Even though Rent-A-Drum and the City do not share any formal contracts with regard to waste collection and recycling, the two are working together to achieve the mutual goal of improved recycling in the city. The City of Windhoek contributes to Rent-A-Drum's recycling initiatives by promoting the clear bag system and encouraging people to recycle. One major initiative for recycling awareness in Namibia is the Schools Recycling Competition. Schools in the Windhoek area are equipped with separation bins from Rent-A-Drum and the students at the school are encouraged to utilize the bins. The schools which have collected the most recyclable materials per student at the end of the year win cash prizes for their efforts. This competition is meant to encourage students to bring recyclable materials from home, which potentially could increase awareness among students and families.

Finding 2: An authorized and organized cooperative of informal waste collectors operates within the Kupferberg Landfill to recycle material brought in by garbage trucks

An organized cooperative of informal waste collectors has been operating at the Kupferberg Landfill since 2000. This group is headed by Wilka Stefanus, known as Ouma, an informal waste collector who has been working in the landfill since 2000, and its operations are contracted by Rent-A-Drum. This relationship was established during the time period when Rent-A-Drum was the contractor for the landfill. The cooperative of informal waste pickers is permitted by the city to work in the landfill and was never a part of the unauthorized scavenging activities that were shut down by the government in 2013.

Figure 19: Members of the cooperative operating in Kupferberg

Currently as of April, 2014 the group of informal waste collectors consists of twelve individuals. Stefanus, as previously mentioned, is the leader of the organization and deals with all interactions with Rent-A-Drum including pick up of the recyclable materials and payment for recyclables, uniforms, and taxes. Stefanus is assisted by one supervisor Victoria, who is in

charge of record keeping of weights of recyclables collected. The other members assist in the physical collection of recyclables in the landfill.

We also learned that the cooperative focuses their efforts on the collection of recyclable materials that Rent-A-Drum will purchase which includes glass bottles, cardboard boxes, paper, plastic bottles, cans, and other plastics. Estimates of the collection percentages by weight detailed by Stefanus are shown in Figure 20.

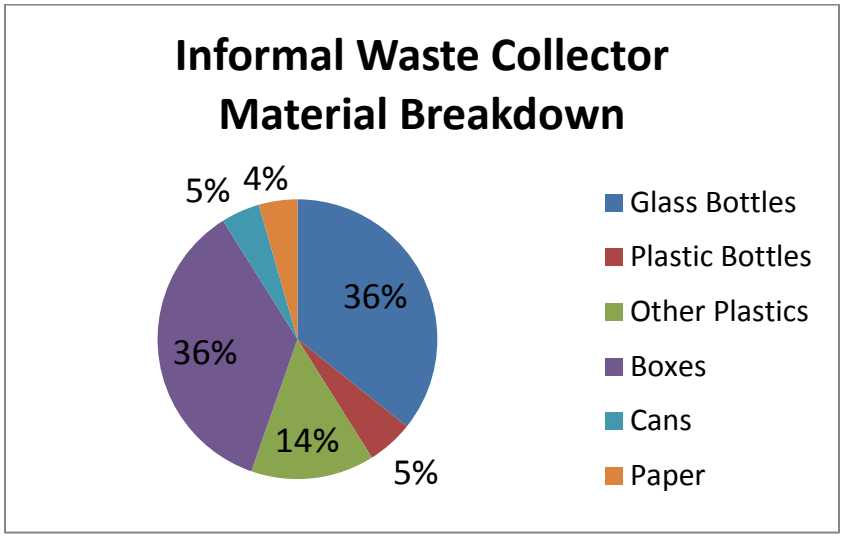

Figure 20: Breakdown of recyclables materials collected by weight in Kupferberg

According to Stefanus, the cooperative never exceeds a total of 120 metric tons of recyclables per month. The organization receives a lump sum payment from Rent-A-Drum once per month based on the prices and weights of the materials, which is divided evenly between everyone. The cooperative collects all types of materials in spite of the difference in selling price because many of the higher value items such as plastic bottles are not as abundant as the lower value items such as cardboard boxes and glass bottles. The prices of the recyclables and a general cost breakdown are detailed in Table 3 below. From each paycheck, Rent-A-Drum deducts the costs of transportation to work, approximately 1200 Namibian Dollars (NAD) for the whole cooperative, as well as uniform costs, approximately N$2500 per month from the whole

cooperative for the last six months. The high uniform fee is mainly as a result of the low retention rates of the majority of the workers in the cooperative. When a new employee is found they purchase a new uniform, but when they leave the uniforms are often not returned and the rest of the cooperative is left paying off the debt. In addition to the fees from Rent-A-Drum, Stefanus manages social security for the cooperative which is deducted for each of the employees. For our purpose of modelling the cooperative's monthly income, we estimated social security to be N$500 per employee. Additional information from our interviews can be found in Appendices E and I.

Type	Price/Tons	Ton/Month	Profit/Month
Glass Bottles	100	40	4000
Plastic Bottles	400	6	2400
Other Plastics	250	16	4000
Boxes	140	40	5600
Cans	250	5	1250
Paper	330	5	1650
Costs		Final	
Uniforms	2500	Total Income	18900
Transport	1200	Total Costs	9700
Social Security	6000	Net Profit	9200

Table 3: Informal waste collector profit breakdown

Finding 3: Recycling in the Kupferberg Landfill is unsuccessful as a result of landfill operations hampering the amount of recyclable material the cooperative can collect

From our interviews with both the landfill site engineer, Dieter Tolke, and the three informal waste collectors, we discovered that the recycling occurring at the Kupferberg Landfill is currently very ineffective. Tolke informed us that approximately 0.4 percent by weight of the total materials that enter the landfill are recycled and sold to Rent-A-Drum. This is extremely inefficient when considering the estimates detailed in the study by Hasheela that 45 percent of the waste that is disposed of at the landfill is actually recyclable material. Based on these two

estimates, we can infer that 44.6 percent of the materials that are buried in the landfill could have been recycled if proper systems were in place.

We learned that there are a small number of recycling transactions that occur at the landfill; however, the primary source for this recycled material is the cooperative of informal waste collectors operating within the landfill. The ineffectiveness of landfill recycling operations was brought to the attention of the government from a campaign to decrease environmental impact from waste collection. As a result, the deputy prime minister of Namibia, Marco Mukosa Hausiku, asked the cooperative of waste collectors to increase their monthly output of recyclables from the current 120 metric tons to 150 metric tons. Stefanus informed them that this would not be possible with the state of landfill operations. The current operations at the landfill are not geared towards incorporating the informal waste collector cooperative which creates several challenges for their operations. The main challenge is the limited time between trucks dumping their waste and the bulldozers spreading those piles across the landfill. As soon as a truck unloads in the landfill the informal waste collectors begin searching through that pile; however, their scavenging is cut short since soon after the bulldozer moves through and forces them away from the pile, as shown in Figure 21. As a result, the informal waste collectors are only able to remove recyclables from the surface of each pile and the rest of the recyclables are forced into the landfill. The cooperative's recycling effectiveness is severely limited by the time they have to collect and a lack of equipment for gaining access to the recyclables once they are buried.

Figure 21: Bulldozer at Kupferberg Landfill

Furthermore, the cooperative is also limited in their recycling operations by the rainfall in Namibia. During the rainy season in particular, the informal waste collectors are often forced to take shelter and halt their activities. Also, during the rainy season Rent-A-Drum is sometimes unable to drive into the landfill for fear of getting stuck in the muck that results from the heavy rainfall. As a result, the cooperative struggles to have their recyclables collected during the rainy season.

5.2 Results of Pilot Program

We begin this chapter with a discussion of our bicycle volunteer, Helmut Uriab. We then detail our findings from operating two pilot programs. Furthermore, we detail several findings that came during our post analysis of the data we collected during the pilot trials. These findings include the feasibility of the pilot runs as well as the potential cost effectiveness for Rent-A-Drum and the informal waste collector operator. Lastly, we discuss the two routes together in a comparison.

Our Bicycle Volunteer Helmut Uriab

We ask Stefanus. During our interview if she could recommend a volunteer for our study. She very willingly said that she would be able to send one of her workers to join us. Stefanus stated that it would have to be a male, of which there are two in the cooperative, since women would not be willing to operate our bicycle cart. We later met Helmut on the day of our first pilot trial with Rent-A-Drum.

Helmut grew up and still lives in Katutura. He never finished his secondary school education and instead began working to help support his family. He has a four year old daughter at home who he works to support.

Before joining the cooperative, he worked for Enviro-Fill, the company contracted by the City of Windhoek to manage the Kupferberg Landfill, for two years. When he worked for Enviro-Fill, Helmut performed odd jobs around the landfill such as picking up stray trash and tending to the grass. Four months ago, Helmut's employment at Enviro-Fill ended and he began working for the cooperative of informal waste collectors. He met Stefanus while he worked at the landfill and she accepted him into the cooperative. Over the last four months, Helmut stated that he "has not been paid" because the decreased profits during the rainy season have broken even with the fees that are deducted from the cooperative for transportation and uniforms.

Helmut disclosed to us that he is familiar with bicycling which was evident when he began the pilot route. During the pilot route operations, Helmut was very efficient, particularly during the at-the-source collection. Helmut was able to quickly assess the contents of the bin and accurately determine the effort he should spend sorting through its entire contents. Also, from the at-the-source collection, Helmut believed that he could collect slightly more recyclables at the landfill. Nonetheless, Helmut showed enthusiasm for both pilot routes and informed us he was

enjoying the work. We also enquired about changes he could recommend about the bicycle cart or pilot route design, but he had little advice for us on improvements.

From our experience with Helmut, we can tell that he has a strong work ethic. Throughout our pilot program he never complained about the difficulty and frequently insisted that he could continue to work for longer. He informed us that the number of households was manageable and he could continue to operate at that rate for a full day. Helmut genuinely appreciated the ability to work and earn an income for himself and his daughter.

Finding 4: Bicycle collection of recyclables is both feasible and safe in Windhoek

During the operation of both pilot routes, we were able to determine that bicycle collection of recyclables is possible for both of our pilot study cases. When operating with Rent-A-Drum, the bicycle cart worked well for collecting and transporting the clear bags of recyclables. The cart was also suited for our second trial and was capable of holding a large amount of recyclables that were sorted from the municipal green wheelie bins.

Figure 22: Helmut bicycling with a full cart of recyclables

The feasibility of the bicycle collection was not solely determined by the carrying ability of the cart but also its operation in the roadways. Throughout the pilot trials Helmut had very little trouble sharing the road on his bicycle. The cart was very maneuverable and did not inhibit the flow of traffic. We operated in the morning during both trials to avoid the peak traffic hour which proved to be very successful. Additionally, the routes were designed to avoid travelling long distances along main roads and instead keep to the more residential streets. This proved to be effective in minimizing vehicle traffic interactions; however, crossing busier streets could not be altogether avoided. Helmut was forced to cross main roadways multiple times which was not a problem with the large bicycle cart.

Figure 23: Helmut bicycling along a busy roadway

Safety was one of our primary concerns during the operation of the pilot trial. During our research we found that many people expressed apprehension about bicycle safety in regards to motor vehicle traffic in a city with almost no bicycle infrastructure. Additionally, we were informed of smaller worries such as dogs attacking the bicyclist. These safety trepidations were set aside after watching the bicycle cart operate. Dogs left Helmut alone and cars were not so aggressive as to put him in danger. While operating we asked Helmut multiple times if he felt unsafe and he assured us that there was no concern.

Finding 5: The collection of Rent-A-Drum clear recyclable bags was relatively effective and time efficient

During and after the pilot trial with Rent-A-Drum, we gathered a significant amount of data to quantitatively analyze Helmut's efforts. We operated in just under a 2 hour period during which Helmut made 4 drop-offs for a total of 54 clear bags collected from 42 different households. The total weight of the recyclables was 222 kg and the weight percentages of the recyclable materials are shown below in Figure 24.

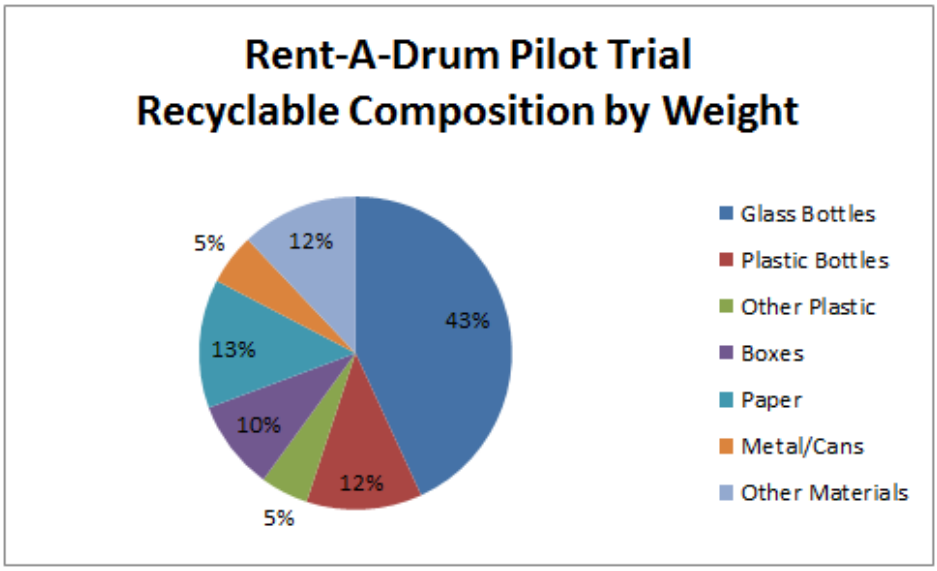

Figure 24: Breakdown of recyclable materials by weight from Rent-A-Drum pilot run

Investigating the effectiveness of this pilot trial solely in terms of the weight of recyclables is not an accurate comparison to truck collection. The Rent-A-Drum trucks used for collecting the clear bags are not limited by weight; instead the volume of materials they can hold limits them. In order to put this into perspective, Figure 25 below shows the Rent-A-Drum truck with all the collected bags inside. We estimated that in 2 hours our bicyclist was able to fill between 50 to 60 percent of the truck with clear bags.

Figure 25: Rent-A-Drum truck after our pilot route

To further analyze the value generated from this pilot study we needed to assess the price that Rent-A-Drum would receive for the materials. We contacted several companies who purchase recyclables both in Namibia and South Africa to find pricing estimates on processed recyclables. We used the data we collected on the resale prices and the weights of each recyclable to determine that Rent-A-Drum could sell the materials for approximately N$279.62 as shown in Table 4.

Rent-A-Drum Collection			
Recyclable	Weight (kg)	Value per Ton (NAD)	Resale Price (NAD)
Glass Bottles	95.60	760	72.66
Plastic Bottles	26.55	3650	96.91
Other Plastic	11.00	700	7.70
Cardboard	20.65	1050	21.68
Paper	29.50	2100	61.95
Metal/Cans	11.70	2000	23.4
Other Materials	26.80		N/A
		Total Profit	**284.30**

Table 4: Financial analysis of Rent-A-Drum pilot run

Initially, we hoped to fully analyze the costs of Rent-A-Drum's recyclable collection, but we found ourselves unable to acquire any data on operational costs from Rent-A-Drum. To estimate the reduced operational costs we performed our own analysis. We researched a Kia flatbed truck, the brand Rent-A-Drum utilizes, and found its fuel economy to be 10.1 km/L. Using the current diesel price in Windhoek of N$12.51 per liter, we calculated that during an 8 km loop a Rent-A-Drum truck would burn N$9.91 worth of fuel. Additionally, each Rent-A-Drum truck is operated by four individuals when compared to our route which required one. The cost of fuel and additional labor are the two main costs that our bicyclist did not incur along his route. Without concrete numbers on Rent-A-Drum's operational costs from truck collection, we are limited to speculation in our analysis of the effectiveness of supplementing this collection with bicycles; however, from our pilot trial it is evident that our bicycle cart collection system can supplement Rent-A-Drum's truck collection. We recorded additional data on street names, number of houses, time lapse per house, number of bags, and other general comments and observations from the pilot route in Appendix S.

Figure 26: Helmut collecting a Rent-A-Drum clear bag

Finding 6: During the at-the-source pilot trial, the value of recyclables collected was comparable to that of the landfill which indicates bicycle recyclable collection could be a sustainable job

During the at-the-source collection pilot trial we weighed and sorted all of the recyclables that Helmut collected. Using the pricing information we gained from Stefanus, we were able to produce an estimate of the total resale value. In Figure 27 we show the weight percentage breakdown of the 125 kg of recyclables collected. In Table 5 we show the weights of each type of recyclable as well as the total resale value of N$26.31.

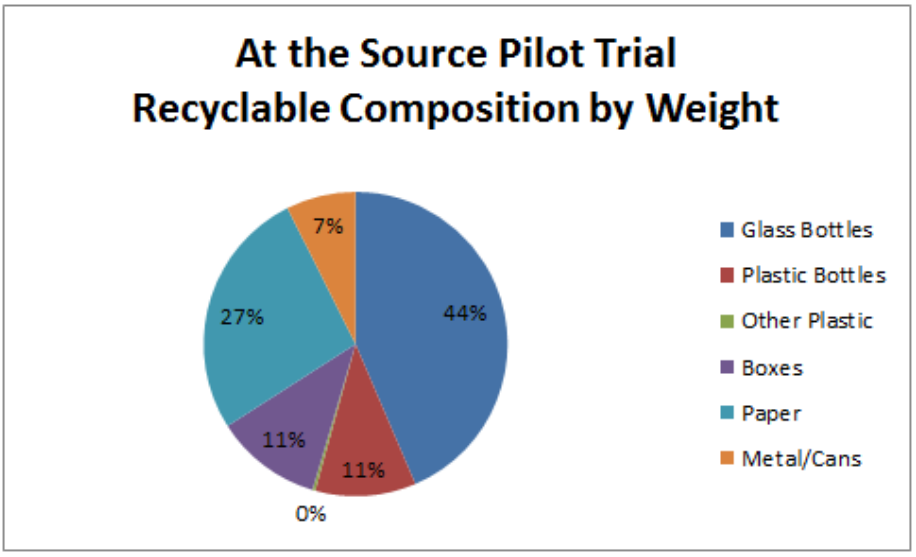

Figure 27: Breakdown of recyclable materials by weight from at-the-source pilot run

At The Source Collection			
Recyclable	Weight (kg)	Value per Ton (NAD)	Net Worth (NAD)
Glass Bottles	54.70	100	5.47
Plastic Bottles	13.45	400	5.38
Other Plastic	0.40	250	0.10
Cardboard	14.25	140	2.00
Paper	33.45	330	11.04
Metal/Cans	9.30	250	2.33

Total Revenue	26.31
Hours	3
Hourly per Person	**8.77**

Table 5: Financial analysis of At-The-Source pilot run

These numbers alone are not enough to ascertain the effectiveness of at-the-source bicycle collection of recyclables as a means of income. To ascertain the job potential, we had to compare these numbers from one individual bicyclist to one individual informal waste collector at the landfill on an hourly basis. Our bicyclist worked for three hours so in one hour he collected approximately N$8.77 worth of recyclables. For the Kupferberg cooperative we had to extrapolate using our limited information on their collection. From Stefanus, we were given an approximate breakdown by weight of the recyclables that the cooperative collects. Assuming that all 12 workers operated for just over 8 hours each weekday plus an additional 4 hours on Saturday during a 4 week month, we found that in one hour an individual waste collector from the cooperative collects approximately N$8.46 worth of recyclables, as shown in Table 6 below.

Monthly Landfill Collection			
Recyclable	Weight (Tons)	Value per Ton (NAD)	Net Worth (NAD)
Glass Bottles	40	100	4000
Plastic Bottles	6	400	2400
Other Plastic	16	250	4000
Cardboard	40	140	5600
Paper	8	330	2640
Metal/Cans	5	250	1250

Total Revenue	19890
Number People	12
Weeks/Month	4
Hours/Week	49
Hourly per Person	**8.46**

Table 6: Financial analysis of landfill cooperative

In one hour of operating with the bicycle, Helmut was able to create approximately N$0.30 more in value than he would normally at the landfill. This shows that at-the-source bicycle collection has potential to become as reliable of a source of income as the landfill collection. When taking into consideration that this was the first such bicycle collection for Helmut we can assume that with practice he would be capable of collecting even more in the future, as most jobs have a learning curve. Overall, at-the-source collection has a large potential to become a steady source of employment. Further data from this pilot route can be found in Appendix T.

Figure 28: Helmut sorting through a green wheelie bin

Finding 7: The working conditions of operating the bicycle in both pilot studies were preferred to the conditions of working in the landfill

From our operations we were able to ascertain that the working conditions of both pilot trials were preferable to the conditions that Helmut currently faces in the landfill. Helmut described many of the aspects of working in the landfill that make the work particularly challenging. The primary complaint was the distance that he had to trudge through the waste on foot to bring the recyclables he found to their sorted piles. He said that during the rainy season "[his] feet sink" into the landfill making the walk even more difficult. Not only is it difficult to walk through the terrain of the landfill but the bag he carries is often very heavy. Helmut also mentioned that ergonomically, working at the landfill is tougher because he spends much more time bending over to dig through the trash. Lastly, he brought up that while operating outside of the landfill the smells he had to endure were much more tolerable.

We also asked Helmut about the challenges he faced during our bicycle collection routes. The primary difficulty for the bicycle collection was hills. Helmut often had to dismount and push the bike when he reached a hill with a full cart. When referencing the challenge of hills he stated that "if I was alone I would just have to do it." In spite of this challenge, Helmut still

firmly believed that this was preferable than his work at the landfill and the challenges would not inhibit him from working a full day.

Figure 29: Helmut walking the full bicycle cart uphill

Rent-A-Drum and At-The-Source Route Comparison

The Rent-A-Drum supplemental route and the at-the-source collection both had their own advantages and disadvantages. During the Rent-A-Drum route, Helmut was able to collect almost twice as many recyclables by weight than at-the-source in an hour less time. Nonetheless, this was to be expected since he simply had to grab bags instead of sort through an entire waste bin for recyclables.

From an environmental standpoint the two pilot routes had different positive outcomes. The Rent-A-Drum collection created a slight reduction in fuel consumption from using trucks. The at-the-source collection benefited the environment by removing recyclables from the solid waste stream that would normally have ended up in the landfill, while the materials from the Rent-A-Drum collection were already removed from the solid waste stream. Both of these are significant environmental benefits but their effects are difficult to compare quantitatively.

When comparing the two different bicycle collection systems from a working conditions standpoint, Helmut preferred at-the-source recycling. After our first trial with Rent-A-Drum,

Helmut told us that “it was fun.” However, after the at-the-source collection he specifically told us he preferred this method. The Rent-A-Drum collection was a constant on the go process because the bags were readily accessible for quick collection, whereas the at-the-source route involved stopping and standing while sorting through the trash in the bin. For this reason Helmut found at-the-source recycling to be easier work. In Chapter 6 we detail our recommendations for moving forward with our project.

6.0 Conclusions and Recommendations

From the information that we collected during our initial interviews as well as our pilot study, our group has developed a set of recommendations. We have divided our recommendations into four different sections: modifications to the bicycle cart, Rent-A-Drum supplemental route, at-the-source collection route, and future project direction. There are many organizations we have worked with that we hope, through collaboration, can carry these recommendations forward, including the Bicycle Empowerment Network of Namibia, the Recycle Namibia Forum, Rent-A-Drum, or student groups at the Polytechnic of Namibia.

6.1 Modifications to the Bicycle Cart

We recommend that the bicycle cart is equipped with a breaking mechanism for hill stops. One of the minor hindrances when using the bicycle cart was parking, especially along an incline or decline. To prevent this issue in the future, we recommend the manufacturer of the bicycle attach chocks or rollback blocks on the wheels which can be applied to inhibit movement.

We recommend that the upper frame of the bicycle cart is manufactured using lighter steel. When operating the bicycle cart, weight was a major concern. Our current cart design used the same size steel piping for the entire frame. Using thinner steel tubing along the top of the frame, where the cart does not receive as much stress, could potentially reduce the overall weight of the cart.

We recommend that the bicycle cart is manufactured with wheel shielding from the canvas bag. To protect the wheels of our cart from rubbing against the canvas bag, we tied several nylon ropes around the frame to constrict the sides of the bag. We chose this method because it was lightweight, inexpensive, and very quick; however, we do not believe that it can

be used as a permanent solution. As a result, we think the cart should be manufactured with a more permanent and effective form of wheel shielding to prevent wheel to canvas contact.

We recommend that the visibility of the bicycle cart is increased. One major concern when considering bicycling in Windhoek or other cities around the world is visibility to drivers. To increase this visibility, we believe that either the cart should be painted a bright color or a brighter color canvas bag should be used than the gray one which we installed. In addition to brighter coloration for daytime visibility, nighttime visibility for the bicycle cart needs to be addressed. To increase nighttime visibility, reflectors should be attached to the rear of the bicycle cart.

We recommend that the bicycle cart is manufactured so that it can be easily disassembled. Our cart was large and bulky which served the purpose of collecting a large amount of recyclables in one trip, but it is cumbersome and too large to store in a small home or shack, a problem assuming that recycling riders would maintain and keep the bikes. Because of this issue, we believe that the cart should be manufactured as a set of parts which can be assembled or disassembled at any time. This would provide a greater manufacturing challenge but would make the cart significantly more manageable.

We recommend that the bicycle cart be manufactured by a professional welder. We believe that a professional welder should be contracted for future cart manufacturing. A more experienced welder will be able to manufacture more complex designs which could potentially increase the practicality of the bicycle cart. Moreover, if any cracks that appear in the frame of the cart at the welds, it is most likely due to potential flaws in the execution of the welding, rather than in the cart design. Any cracks or imperfections found along the connection rod or the wheel brackets could reflect design issues.

6.2 Rent-A-Drum Supplemental Route

We recommend that a student group from the Polytechnic and Rent-A-Drum continue to investigate the savings that could accrue to Rent-A-Drum from bicycle recyclable collection. Without access to data related to Rent a Drum operations, we were unable to conduct a least cost analysis comparing the two collection methods. To understand the potential cost saving and environmental benefits from bicycle collection, Rent-A-Drum will have to analyze the data from our pilot route. In addition, our study was limited by the short time we had in Windhoek. Consequently, we were only able to perform one pilot trial run for recyclable collection. Although we did collect a sufficient amount of data to begin analyzing the program, a student group should run more trials with the bicycle cart to collect a larger set of sample data for analysis.

We recommend that a student group from the Polytechnic performs a pilot route operation in a higher income area of Windhoek. During our study we operated within Windhoek West which is considered a middle income region of Windhoek. According to the information we received from Rent-A-Drum, Windhoek West participates in clear bag collection, but does not produce as many bags as higher income regions. Based on the experience from our study, we believe that a greater clear bag participation density within a region would be suited for bicycle collection. The bicycle operator would be capable of collecting enough recyclables to fill the collection truck very efficiently; therefore, the truck could spend more time driving back and forth to the material recovery facility instead of driving around the neighborhoods. Consequently, future pilot trials should be operated in high income regions to determine the feasibility of the bicycle cart collection under different conditions.

We recommend that Rent-A-Drum invests in multiple bicycles and temporarily employs three to four bicyclists. The idea behind this research is not to employ one bicyclist but several working together to collect recyclables. One bicycle operator proved to be successful, but to accurately understand the practicality of bicycle collection more bicycles need to be produced and operated on a small scale. We think that Rent-A-Drum should make the small investment in several bicycle carts and temporarily employ three to four operators. These operators would be employed to work within a small section of a normal Rent-A-Drum route on their collection days. This would take the pilot trial that we have developed and expand it into a longer term case study. A case study would be extremely beneficial for increasing the amount of information and determining the effectiveness of bicycle collection.

When performing this case study, it would be ideal for Rent-A-Drum to allow the bicyclists to operate within an area that they would normally not reach until later in their collection day. This would prevent the truck drivers from having to completely change their routes. From our pilot trial, it is clear that three to four bicyclists would be capable of filling a Rent-A-Drum truck every hour. As a result, they would need a truck to periodically stop at the drop-off to take the collected recyclables back to Rent-A-Drum. Because payment by weight would be an added complication for ensuring that the recyclables collected were not mixed with what the truck collected, we recommend paying the bicyclists an hourly wage for their labor. Additionally, an hourly wage would eliminate the need for a party sorting recyclables at the drop off.

The bicyclists will also need some form of management, especially during the first operations of the trial period. For this we believe that Helmut Uriab, the volunteer from our pilot study, would be appropriate for the job. Helmut is already familiar with the system and proficient

at the work involved, making him ideal for leading the group. As for the hiring of additional riders, we recommend working with the Kupferberg cooperative to find for willing informal waste collectors. These people are familiar with the Rent-A-Drum clear bags as well as locations in which they are prevalent. We do not recommend transferring truck operators to the bicycles because this may seem like a demotion from their current positions.

6.3 At-the-Source Collection Route

We recommend that the operator starts the route at 04:00. During our experience operating this pilot trial of at-the-source collection, we found that beginning at 05:00 was not early enough. When we attempted to move to a different neighborhood from where we began operating, we encountered already empty green wheelie bins from the city's collection. As a result, our volunteer, Helmut, recommended that we begin even earlier at 04:00. Starting earlier could also help to keep operations during the cooler part of the day. Also, we saw numerous informal waste collectors searching for bottles and beginning earlier could help avoid any confrontation.

We recommend that a minimum of four operators be used for a single collection route. While Helmut bicycled along the route, we left a group of two behind to sort the recyclables at the drop-off point. When operating this collection route outside of our research study, it would be time inefficient for operators to both collect at the households and sort recyclables at the drop-off. In addition, other informal waste collectors we encountered asked us for the bottles we had collected at the drop-off, which they sell to bars in the informal settlements. They would likely have taken bottles from our pile if it had been left unguarded. Therefore, we would advise that for the at-the-source collection, several bicyclists operate with one drop-off location sorter. Using several bicyclists to one sorter would decrease the idle time

of the sorter and also increase the total intake for all of the operators as opposed to operating one to one.

We recommend that the operators dump the recyclables on a tarp or utilize a rake or shovel for clean-up at the drop-off location. One small issue that we found when sorting the recyclables at the drop-off was avoiding leaving any trash on the ground. We spent five to ten minutes cleaning up at the end of our operation. To make this process more efficient we recommend investing in a tarp to dump the recyclables on or being prepared with a rake or shovel to clean at the drop-off location.

We recommend that this form of recyclable collection be operated by the cooperative of informal waste collectors at the Kupferberg Landfill. We believe that the best way to organize this group is as a cooperative. From the cooperative at the landfill, we have seen that this kind of social organization can be a very effective method for managing a small scale operation for recyclable collection in Windhoek. The bicycle recycling cooperative could be operated as a secondary business by the cooperative at the landfill. The head of the operation, Wilka Stefanus, is interested in expanding operations. By becoming a part of the landfill cooperative, the bicycle recyclers could avoid many logistical issues of establishing a new cooperative, such as transport, payment, uniforms, social security contribution, and most importantly establishing a relationship with Rent-A-Drum to collect the sorted recyclables.

We recommend the Recycle Namibia Forum finds an organization to sponsor several bicycle carts for the cooperative. Although the bicycle carts would not be a large investment for a company such as Rent-A-Drum, the upfront cost may be too much for the cooperative of waste collectors to fund on their own. One way that this problem could be mitigated is by finding an organization that is willing to subsidize the costs through a

sponsorship. Many companies sponsor green initiatives as well as charities which is something that should be looked into. This could prove to be mutually beneficial relationship by enabling the cooperative to afford the bicycle carts and creating positive public relations for the sponsoring organization. The Recycle Namibia Forum would be ideal for this recommendation because of their connections with companies interested in recycling.

Potential sponsors of the program could include companies involved with recycling, for instance Rent-A-Drum. The bicycles themselves could be sponsored or donated by cycling shops like Cymot, or the materials for the cart could be subsidized hardware stores such as by Pupkewitz MegaBuild or Build It stores. Additionally, the Recycle Namibia Forum could seek sponsorship through large companies that sponsor green initiatives such as Nedbank. In exchange for the sponsorship, the bicycle cart could display sponsor's name or logo on the side of the canvas bag.

We recommend the Recycle Namibia Forum looks into approving several drop-off points through The City of Windhoek. One remaining logistical question for the operation of bicycle collection is finding suitable central drop-off locations. Initially, we believed that we would be able to utilize the satellite dump sites for these locations; however, after further consideration we determined that they are too far outside of residential areas to be time efficient. This left us using a street corner as a drop-off point which was suitable for our collection trial but is not a long term solution because of our proximity to a resident's property without their consent. To finalize the design of a pilot route, the city needs to approve local drop-off points. The Recycle Namibia Forum is already well connected with the City of Windhoek and would be capable of connecting with locals to have drop-off locations approved.

We recommend that a student group from the Polytechnic researches the feasibility of recyclable collection by bicycle in Katutura. Currently, in Katutura there is little recycling occurring and Rent-A-Drum has no plan to expand recycling to the informal settlements. This means that there could be a large market for recyclables that are currently being disposed of via the City of Windhoek trash collection. Additionally, there are many parts of Katutura that consist of narrow dirt roads making them inaccessible to truck collection. This is where the bicycle cart could potentially thrive for recyclable collection as there is currently no alternative method capable of servicing these areas.

Many of the key informants we interviewed as well as Helmut, our pilot program volunteer, have suggested this as a use for the bicycle cart. Operating in Katutura has other advantages including spreading recycling awareness amongst a population that generally lacks knowledge on the subject. The bicycle cart could become part of a larger recycling awareness campaign when residents of Katutura see that many of these materials they are throwing away have some value to the bicyclist. Eventually, people would come to expect the presence of recycling in their neighborhoods. Recycling in Katutura would provide many challenges but should be assessed further for feasibility of bicycle collection.

6.4 Future Project Direction

6.4.1 Establishment of a Bicycle Cart Industry

We recommend that BEN Namibia assesses the feasibility of establishing a bicycle cart manufacturing company. If the idea of recyclable collection via bicycle moves past the preliminary research stages there will be a demand for bicycle carts. This is an opportunity to establish a secondary industry in bicycle cart manufacturing and maintenance. By establishing a small company that can manufacture these carts, more jobs could be created.

BEN Namibia is a suitable organization to involve in establishing this bicycle manufacturing industry. They have already shown considerable support for the recycling project and have aided us with the initial design of the bicycle cart. BEN Namibia focuses their efforts on generating sustainable bicycle industries around the country which is strongly connected to the idea of generating a bicycle cart manufacturing company. BEN Namibia already has experience in establishing bicycle industries and could prove to be a vital player in moving this idea forward; however, BEN Namibia would be limited in its ability to develop a feasibility study. To aid in the process of starting company, a student group from the Polytechnic should perform a research study on the potential demand for and the practicality of establishing an industry around bicycle carts. The study should include research on alternative uses for the bicycle carts. Although recyclables collection was the intent for the cart design, there could potentially be more uses for an inexpensive mode of transporting materials. Researching some of these alternative uses could help to expand the consumer base for the proposed cart manufacturing industry.

Furthermore, if a bicycle cart manufacturing industry were to be established, there would need to be a consumer for the final product. In order to increase the number of consumers a marketing campaign would need to be developed for the bicycle. This should include searching for other uses of the cart. It could also include branding the bicycle cart to make it more recognizable. There are many organizations that could play a crucial role in marketing the bicycle cart including BEN Namibia, the Recycle Namibia Forum, Rent-A-Drum, or a student group at the Polytechnic. These organizations should collaborate on the marketing campaign to ensure its effectiveness.

6.4.2 Instituting Recycling in New Regions of Namibia

We recommend that a student group from the Polytechnic researches using the bicycle cart to begin recycling in regions of Namibia that have no formal recycling operations. Although our study specifically focused on recycling systems in Windhoek, we believe that bicycle cart collection could serve a much broader purpose. Bicycle cart collection could be utilized to establish recycling systems in areas of Namibia that currently have none. One of the main benefits of using bicycle collection is that there are no large upfront investment costs of purchasing collection trucks. Individual towns could purchase bicycle carts and employ operators to collect recyclables from trash bins in a similar fashion to our at-the-source pilot trial. Towns could also attempt to promote a system similar to the clear bags of Rent-A-Drum and cyclists could be employed to collect the bags.

One of the major constraints to establishing recycling systems around Namibia is the lack of proper facilities to manage recyclables. As a result, recyclables need to be transported to Rent-A-Drum's material recovery facility in Windhoek if they are to be dealt with properly. Transporting recyclables across the country would likely not provide enough revenue to be justifiable from a financial standpoint. To deal with this transport dilemma, the student group should research the possibility of incentivizing commercial trucks that would normally return to Windhoek empty to instead carry recyclables with them. This could either be in the form of a monetary reward or a tariff for travelling to Windhoek empty.

The student group should perform a set of studies around Namibia modeled after our pilot study in Windhoek. Separate investigations should be performed for Northern Namibia, where greater populations are generating large amounts of waste, coastal towns such as Swakopmond

and Walvis Bay, where recycling initiatives are beginning to take hold, and rural Namibia, where truck collection would not be cost efficient.

6.5 Conclusion

The Polytechnic of Namibia formed the initial concept for our project to revolutionize recycling processes and generate employment opportunities for informal waste collectors in Windhoek. We took this concept and modeled it through two pilot trials. The first pilot trial involved collecting Rent-A-Drum clear bags while the second utilized sorting recyclables at-the-source from household waste bins. After running our pilot trials, we found that bicycle collection of recyclables was feasible in both instances. We found that the Rent-A Drum route has potential as a supplement to truck collection and at-the-source collection actually generated slightly more hourly profit than the landfill collection by the cooperative, while providing preferred working conditions for the volunteer compared to his working conditions at the landfill. We used these results and findings to develop a set of recommendations which seek to move our project forward past the preliminary stages of our research. Additionally, our recommendations aim to expand the scope of our project from recycling in Windhoek to applications around Namibia. We present these recommendations to the Polytechnic of Namibia and Rent-A-Drum in the hope that work will continue in assessing the potential economic and environmental benefits of bicycle recyclable collection as well as its capacity to generate jobs in Namibia.

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Appendices

Appendix A: City of Windhoek Household Refuse Removal Programme

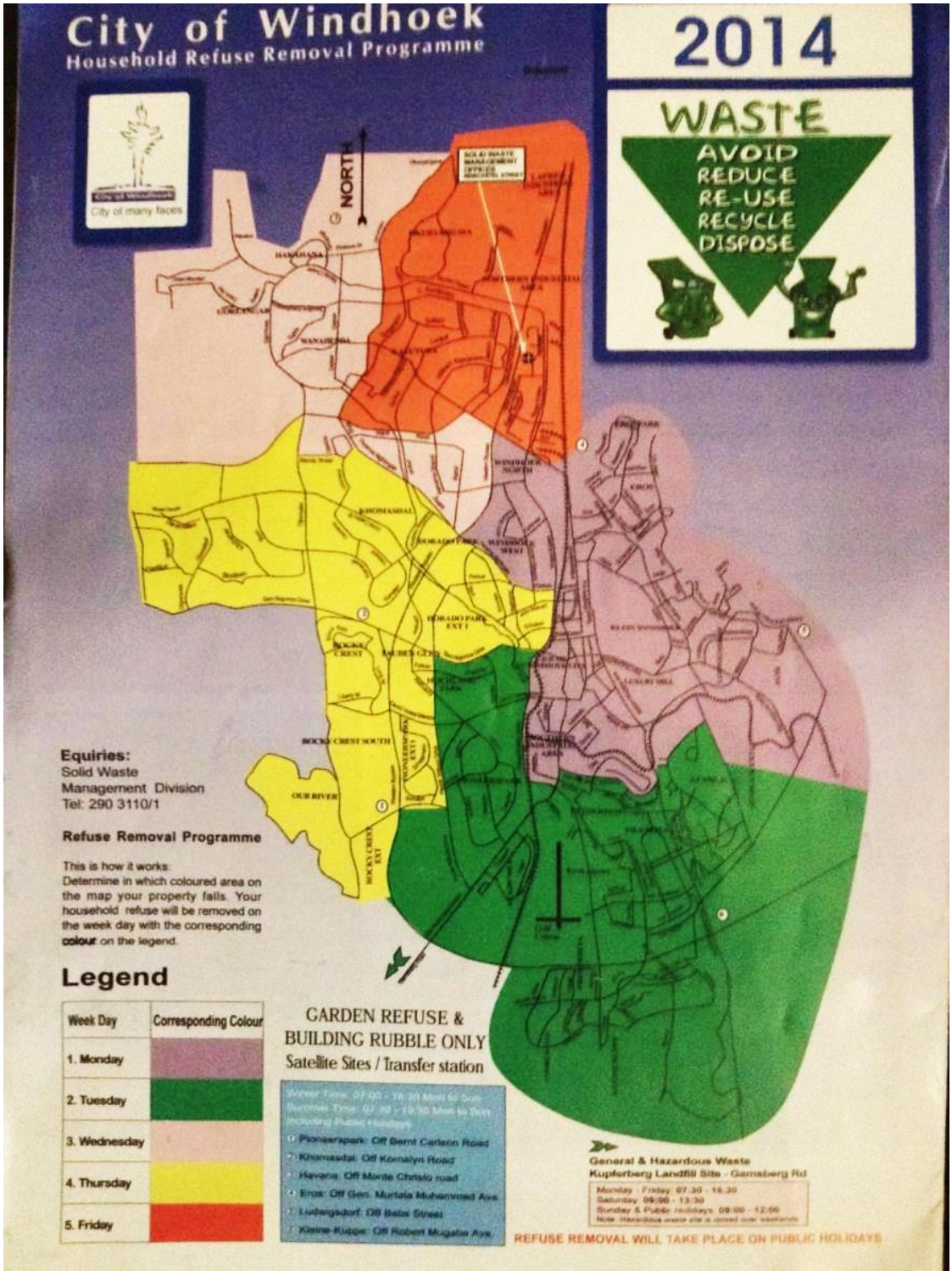

Figure 30: City of Windhoek household refuse removal programme

Appendix B: Interview with Pedal People

B-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with Pedal People to learn more about how your cooperative works and how it might relate to our project in Windhoek. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

B-2 Questions for Ruthy Woodring of Pedal People

Interview conducted on February 5, 2014.

Interview was conducted over the phone.

During our background research on the project, while looking for information regarding bicycle waste collection, we found Pedal People. Pedal People is a cooperative based in Northampton MA that specializes in bicycle waste collection. The goal of this interview was to learn about the workings of an established bicycle waste collection organization.

Question:

1. What is the history behind Pedal People?
2. How many costumers does Pedal people serve?
3. What is the average work day for an employee of Pedal People?
4. What kind of equipment is used for bicycle waste collection?
5. What are the physical barriers to this job and how do you cope with them?
6. Any advice for our project?

Appendix C: Interview with Bicycle Empowerment Network of Namibia

C-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting an interview with BEN Namibia to gain an understanding of your projects and their successes in Windhoek and other regions. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

C-2 Questions for Michael Linke of BEN Namibia

Interview conducted on March 16th, 2014.

Interview was conducted at the Physically Active Youth center outside Katutura in Windhoek, Namibia. We visited a trailer in which BEN Namibia keeps their bicycles and other equipment. We looked at the bicycles they use for their ambulance project and received a demonstration on how their trailer stretcher works.

Questions:

1. How did you start BEN Namibia?
2. What is the history of the bicycle ambulance program?
3. What are some of the key designs of this trailer?
4. What challenges did you face when deploying these ambulances in the field?
5. Did the distribution of bicycles by BEN Namibia ever create secondary industries?
6. What are some of your goals for the future of BEN Namibia?

Appendix D: Questions for Recycle South African Institute for Environmental Assessment

D-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting an interview with the South African Institute for Environmental Assessment (SAIEA) to understand the situation of current recycling system in Windhoek. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

D-2 Questions for John Pallett, SAIEA

Interview conducted on March 25th, 2014.

The interview was conducted in Pallett's office in the SAIEA building in Windhoek.

The SAIEA building is located down the street from the Polytechnic of Namibia. This was an informal interview which we set up in the hopes that he could provide some documents about the current recycling methods in Windhoek as well as connect us with key informants who might be able to help us with our project. He provided us with a few documents, including the State of the Environment Report on Waste Management and Pollution Control. He also gave us the contact information for Anita Witt, the coordinator of the Recycle Namibia Forum.

Appendix E: Interview with City of Windhoek Solid Waste Management Division

E-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with various Windhoek Solid Waste Management Division personnel to learn more about the city's role in recyclable collection and their relationship with private recycling companies. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

E-2 Questions for Dieter Tolke, Kupferberg Landfill Site Engineer

Interview was conducted on March 26th, 2014.

Interview was conducted at the Kupferberg Landfill in Windhoek.

Tolke took us on a tour around the landfill while giving us a description of the landfill operations. There are different sections of the site that have different functions. There is a recycling section which he explained to us is currently underutilized. He also showed us the informal waste pickers and introduced us to their boss, Wilka Stefanus.

Questions:

1. What do you do as a site engineer?
    - How long have you worked here?
    - What is your day to day routine?
    - How often are you at the landfill?
    - General ice breaker questions about his job/work
2. Can you describe to us the general activities around the landfill?
    - Who else works here?
    - What do they do?
3. Logistics of the landfill
    - Who dumps in the landfill? Rent-A-Drum? City of Windhoek?

    - Do you have information about how much? Is this information we could get access to?
    - Are there schedules of when and how often they dump waste?
    - How much do they pay? How does that work? Residential vs. Businesses?
    - Do they pre-sort any of the recyclables from the waste before sending it into the landfill?
    - How quickly is the landfill running out of space?
    - Are there any challenges?
4. Are there recycling programs in place?
5. How big of a problem were informal waste pickers in the past?
    - What did they collect?
    - How did they operate?
    - Are they still a problem?
    - Is there any sort of relationship between them and the City?
    - Are there any plans?
6. We have heard about the existence of a group who works to sort out recyclables in Kupferberg.
    - Who are these people?
    - What kinds of recyclables are salvaged?
    - How much time do they spend at the landfill?
    - Are they associated with any company?
    - Would it be possible for us to set up a meeting with some of these workers at another time in the upcoming weeks?
7. Can you think of any areas that need improvement in the overall process?
    - Is there anything that you would change about the collection and transportation that would make your operations at Kupferberg more efficient?

Appendix F: Interview with Rent-a-Drum Employees

F-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with various Rent-A-Drum employees to learn more about their daily operations and routes around the city of Windhoek. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

F-2 Questions for Rohan Louw, Business Developer at Rent-A-Drum

Interview was conducted on March 27th, 2014.

Interview was conducted at the Rent-A-Drum facilities in Windhoek.

We interviewed Rohan Louw from Rent-A-Drum in order to get a better understanding on how general waste management is handled in Windhoek as well as how Rent-A-Drum handles their recycling. For our project we would also like to analyze the costs of Rent-A-Drum's collection methods to compare to collection with bicycles.
Rohan walked us through the Rent-A-Drum recycling facilities, allowing us to take pictures as he gave us the tour. Below are the questions we asked Rohan during our tour of the facilities.

Questions:

- Can you give us some background on Rent-A-Drum and as a private waste collection company?
- How does Rent-A-Drum collect recyclable waste?
- How many trucks does Rent-A-Drum operate?
- How many employees does Rent-A-Drum have?
- How do you find new workers?
- What are the requirements for working here?
- How does the sorting facility work?
- How much waste is collected from each clear plastic bag?
- Which days are they collected?

- What time is waste collection started?
- How do people acquire the bags if they do not have them?
- How successful is this process?
- We had an interview with the cite engineer at the Kupferberg Landfill two days ago and we met a woman there, Wilka Stefanus, who sorts recyclable waste from the landfill. How much waste do you get from her and her workers?
- How do you compensate them?
- What materials do you mostly get from them?
- What is your relationship with the city?
- Does the city help support your operations from a financial standpoint?
- How profitable is the recycling process?
- Why is recycling with the clear bags not performed in the informal settlements such as Katutura?

Appendix G: Interview with City of Windhoek Solid Waste Management Division

G-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with various Windhoek Solid Waste Management Division personnel to learn more about the city's role in recyclable collection and their relationship with private recycling companies. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

G-2 Questions for Stellio Tsauseb, Section Engineer for the Landfills

Interview was conducted on April 1st, 2014.

Interview was conducted in Stellio Tsauseb's office in the City of Windhoek Solid Waste Management building in Windhoek.

We interview Tsauseb to gain a better understanding of how the city collects waste. Additionally, we were interested in city's relationship to Rent-A-Drum as well as their involvement with the clear bag recycling program.

Questions:

1. What do you do as a section engineer?
    - How long have you worked here?
    - What is your day to day routine?
    - How often are you do you visit the landfill?
    - General ice breaker questions about his job/work
2. Logistics of the Kupferberg landfill
    - Who dumps waste in the landfill? Rent-A-Drum? City of Windhoek?
    - Do you have information about how much? Is this information we could get access to?
    - Are there schedules of when and how often they dump waste?

- How much do they pay? How does that work? Residential vs. Businesses?
- Are there any challenges?

3. Could you tell us a little bit about these landfill satellite sites?
    - Who typically disposes of waste here?
    - Are they located in the residential areas, industrial areas, or on the outskirts of the city?
    - How do these transfer stations work?
    - Does the city charge the residents for the use of these sites?
    - Can we see some of the data regarding how much waste is collected at each site and the breakdown of what type of waste is collected in what amounts?
    -
    - Is there a map of these sites?
    - Would it be possible for us to use these sites as a drop off point during our project?
4. Rent-A-Drum
    - What is the city's relationship with Rent-A-Drum?
    - What are your views in terms of the benefits from Rent-A-Drum's operations from the city's point of view?
    - Is the clear bag system a Rent-A-Drum project or a city of Windhoek project?
    - Does Rent-A-Drum receive any subsidies from the city?
    - Does Rent-A-Drum rely on the city?
        - Monetarily?
        - For rights to recyclables?

5. Does the city of Windhoek participate in any recycling projects?
    - Is this something the city is looking into?
    - Are there any long term plans related to recycling?
6. Do you have any general advice about our project?
    - Are there any contacts you would recommend we meet with?
    - Is there anyone who can give us more information about the specific routes?

Appendix H: Interview with Recycle Namibia Forum (RNF) Coordinator

H-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with RNF to learn more about the City's current state of recycling. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

H-2 Questions for Anita Witt, RNF Coordinator

Interview was conducted on April 2nd, 2014.

Interview was conducted in our office at the Polytechnic of Namibia.

Questions:

1. Can you tell us about your job as the Coordinator for the Recycle Namibia Forum
    - How long have you worked here?
    - What is your day to day routine?
    - What are your responsibilities?
    - General ice breaker questions about her job/work
2. Recycle Namibia Forum
    - Can you tell us more about the forum?
    - How long has it existed?
    - Who is involved?
    - What kind of influence does the forum have on policies?
    - Are there any projects that the forum is working on?
    - Can you tell us about the school recycling competition?
    - What does the forum see as the major challenges for recycling?
3. Can you tell us a little bit about your job as a writer for the Namibian?
    - You wrote specifically about bicycles correct?
    - What is the bicycle culture like in Windhoek?
    - Is the bicycle culture changing over time?
    - Have you heard of any projects similar to what we are undertaking?
    - Were they successful?
    - Do you have any contacts that might be beneficial to us?

- What kinds of challenges do you foresee for a bicycle related industry in Windhoek?
- Are there regions of Windhoek that are more bicycle friendly?
- What about the rest of Namibia?

4. Informal Waste Collectors
    - Has the RNF dealt with issues around informal waste collectors?
5. After hearing about our project do you have any recommendations for us moving forward?

Appendix I: Interview with City of Windhoek Solid Waste Management Division

I-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with various Windhoek Solid Waste Management Division personnel to learn more about the city's role in recyclable collection and their relationship with private recycling companies. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

I-2 Questions for Miriam Omonigbehin, Education and Marketing

Interview was conducted on April 3rd, 2014.

Interview was conducted in Miriam's office in the City of Windhoek Waste Management office building in Windhoek.

Questions:

1. What do you think about our project?
2. What are you suggestions for our project?
3. What are some of the areas of recycling that you work with?
4. Is Rent-A-Drum involved with the education and marketing division?
5. For our project we are looking into having some drop off points for the bikers to offload their collected recyclables and then continuing on their routes, do you have any suggestions for where we might be able to do this?
6. What is your contact information if we have any further questions?

Appendix J: Interview with Informal Waste Collectors at the Kupferberg Landfill

J-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with the informal waste collectors at the Kupferberg Landfill to gain an understanding of their role in the recycling system of Windhoek. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

J-2 Questions for Wilka Stefanus and Other Informal Waste Collectors

Interview was conducted on April 8th, 2014.

Interview was conducted at the Kupferberg Landfill just to the side of the general waste collection area. The waste collectors' preferred language was Oshiwambo, therefore we had three students from the Polytechnic of Namibia accompany us to the interview to translate for us.

Questions:

Introduction/History of the workers:

1. How long have you been operating here at the landfill?
2. Can you tell me about your job?
3. How many days a week do you work?
4. For how long do you work each day?
5. Do you do any work outside of the landfill?
6. How long has this group been operating together at the landfill?
7. How did this operation start?
8. How is your group organized? (eg. Is there a committee?)
9. What is your role in this group?
10. Have you always been in this role?

11. Were you around when the informal waste pickers were removed from the landfill?
12. Were you part of the group of informal waste pickers who used to collect from the landfill?
13. How many informal waste pickers were there?
14. How were they removed?
15. Were you forced to leave the landfill?
16. If so, how did you return?
17. Did you work somewhere else before joining the group here at the landfill site?
18. If so, elaborate.

Current Conditions / Logistics:

19. How many of you are working here now? Men? Women?
20. How old are most of the workers?
21. Where did the people working here come from? (former informal waste pickers)
22. What kinds of recyclables do you collect?
23. How much recyclable material do you usually collect in a month?
    - Weight of paper?
    - Weight of cardboard?
    - Weight of plastics?
    - Weight of glass?
    - Weight of metals?
    - Weight of any other materials mentioned?
24. What do you do with recyclables that you collect?
25. Who do you sell the recyclables to?
26. How much does Rent-A-Drum pay for those recyclables? (or any other organizations)
    - Price of paper?
    - Price of cardboard?
    - Price of plastics?
    - Price of glass?
    - Price of metals?
    - Weight of any other materials mentioned?
27. Do you sell recyclables to anyone other than Rent-A-Drum?
28. Do you collect any recyclables for any purpose other than resale?
29. Do you have any other relations with Rent-A-Drum?
30. Do you have a contract with Rent-A-Drum?
31. Who deals with receiving payment from Rent-A-Drum?
32. What happens to the money that Rent-A-Drum pays for the recyclables? (eg. Is it divided between workers? Kept in the bank?) Is this monthly? Daily?
33. Are there things you are working on changing?
34. Are there things that you would change but cannot?

35. Do you do any recycling outside of Kupferberg?
36. Do you feel safe working at the landfill?
37. What are your views on the time you spend collecting recyclables and the money you receive (do you feel it is beneficial)?
38. Are there any challenges with organizing all of the workers?
39. What are the challenges you face with collection of recyclables?

Other Relations:

40. Do you work with the City of Windhoek?
41. Do you have a contract with the city?
42. Are there specific conditions that allow you to work here?
43. If so, what are these conditions?
44. Do you have any relationships with any other organizations?
45. Can you tell us about this relationship?

Our Study

46. When considering a program like this would you recommend trying to contract the workers or running a self-organized operation?
47. Do you think maintaining the bicycles will be an issue?
48. What would you recommend for storing the bicycles to avoid damage or theft?
49. How do you feel about using bicycles to collect recyclables from houses?
50. Do you think this is something both men and women could do? (Are there gender limitations, traditional norms, taboos to riding a bicycle?)
51. What should we keep in mind when designing the bicycles?
52. After hearing about this project, could you see yourself cycling to collect recyclables? (During the piloting phase)
53. If the project is successful, do you see yourself (or member of your group) cycling to supplement what you are collecting from the landfill site?

We will share our results with you, if you are interested, at the end of our study. Thank you for taking the time out of your day to speak with us.

Appendix K: Interview with City of Windhoek Solid Waste Management Division

K-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with various Windhoek Solid Waste Management Division personnel to learn more about the city's role in recyclable collection and their relationship with private recycling companies. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

K-2 Questions for Miya Chipeio, Licensing and Special Projects

Interview was conducted on April 8th, 2014.

Interview was conducted in Chipeio's office at the City of Windhoek Solid Waste Management Division building.

Questions:

1. Can you tell us about your job as the Section Engineer for Licensing and Special Projects
    a. How long have you worked here?
    b. What is your day to day routine?
    c. What are your responsibilities?
    d. General ice breaker questions about his job/work
2. Can you tell us about the general process of getting a project approved?
    a. What does this involve?
    b. Are there formal write ups?
    c. Are there other groups we need to contact?
    d. Does it take a long time?
        i. Would we be able to get it expedited because of our time limitations?
    e. After hearing about our project what kind of process would we have to go through?

3. Can you talk to us about any special projects that might be relevant to our study that have been performed in the past?
    a. Can you tell us about the details of the project?
    b. When did this occur?
    c. Was it successful?
    d. What was their application process like?
    e. What challenges did they face?
        i. Getting approval?
        ii. During operations?
    f. Has the city performed any projects with Rent-A-Drum in the past?
    g. Has the city performed any projects with informal waste collectors?
    h. Can you tell us about a project that has failed in the past?
    i. What caused them to fail?
    j. What challenges did they face?
        i. Getting approval?
        ii. During operations?
    k. Are there project considerations that are often overlooked?

K-3 Second interview with Chipeio

Interview was conducted on April 23rd, 2014

Interview was conducted in Chipeio's office at the City of Windhoek Solid Waste Management Division building.

The second interview with Chipeio was conducted to discuss logistics of our at-the-source pilot route. We submitted a formal request to run our pilot program which was approved. We were looking to finalize any outstanding details of our pilot route.

We met with Chipeio in her office. Tsauseb was there as well and we discussed with them our route for our pilot program. We suggested one neighborhood in which she agreed to let us pilot our program. She also gave us a second neighborhood which she thought would be helpful for us based on our explanation in the proposal. We confirmed with both of them that we could use the Satellite Site number 4, located just outside the Windhoek North area, as our drop off location. Tsauseb gave us the name and contact information of the onsite contractor there. They also said Rent-A-Drum will collect the recyclables from the site on request.

Appendix L: Interview with Pilot Program Volunteer

L-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with you to understand your views and opinions after the pilot program operation. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

L-2 Questions for Helmut Uriab

Interview was conducted on April 24thth, 2014.

Interview was conducted in our office at the Polytechnic of Namibia.

Questions:

Introduction/History of the workers:

1. Where do you live in Windhoek?
2. Were you born in Windhoek or did you originally come from outside Windhoek? Where?
3. How long have you been operating at the landfill?
4. How did you join the recycling group/cooperative at the landfill?
5. What does your job at the landfill entail? Can you tell us about your job?
6. How many days a week do you work?
7. For how long do you work each day?
8. Do you do any work outside of the landfill?
9. What is your role in the cooperative?
10. Have you always been in this role?
11. Were you around when the informal waste pickers were removed from the landfill?
12. Were you part of the group of informal waste pickers who used to collect recyclables from the landfill?

13. If you were part of the informal waste pickers at the landfill, were you forced to leave the landfill?
14. If so, how did you return?
15. Did you work somewhere else before joining the group here at the landfill site?
16. If so, elaborate.
17. Have you ever ridden a bike before for e.g. business activities?
18. Do you sometimes/usually ride a bike in the city or suburb where you live? How comfortable are you with riding bicycles in the city?

Current Conditions / Logistics:

19. What kinds of recyclables do you collect?
20. How much recyclable material do you usually collect in a month?
21. Are there things that you wish you could change with the current cooperative system but cannot?
22. Do you do any recycling outside of Kupferberg?
23. Do you feel safe working at the landfill?
24. What are your views on the time you spend collecting recyclables and the money you receive (do you feel it is beneficial)?
25. Are there any challenges with organizing all of the workers?
26. What are the challenges you face with collection of recyclables?

Our Study

27. How do you feel about using bicycles to collect recyclables from houses?
28. What do you think was difficult about using the bike?
29. What is your opinion on how the pilot program ran?
    a. How did you find it to bike in the different parts of the suburbs, was it easy of difficult?
    b. What did you about the weight of the cart during the piloting?
    c. What are your views on the distance from the houses to and from the drop off location?
30. Do you think the potential problems with the program would affect your work day?
31. If yes, how would these potential problems affect your work day?
32. What do you think about the number of houses in the route?
33. If you were to be given a bicycle, how many hours do you see yourself collecting recyclables from households per day? Or how many households do you see yourself covering per day?
34. Do you see yourself collecting all recyclables or do you prefer to collect only certain materials?
35. If yes, which materials?

36. If the project is successful, do you see yourself (or member of your group) doing this again on a regular basis?
37. Are there any potential problems that you foresee regarding the way that the bicycle is designed?
38. Do you have any suggestions for improving the bike?
    a. Height of bicycle? Too high or too low or okay?
    b. Size of trailer? Is it too large, too small or okay?
    c. Distance of trailer from the ground?
39. Do you like the size of the trailer?
    a. Is it too large or is it difficult to operate due to the size?
40. How did you find the route that we used during the piloting? Are there any changes that you would suggest?
41. If yes, elaborate
42. Do you think collection of recyclables using a bicycle is something that both men and women could do? (Are there gender limitations, traditional norms, taboos to riding a bicycle?)
43. Do you think maintaining the bicycles will be an issue?
44. What would you recommend for storing the bicycles to avoid damage or theft?
45. When considering a program like this would you recommend trying to contract the workers or running a self-organized operation?
46. In terms of payment, if you are contracted what do you think would be a fair compensation for the work done with the bike compared to the work you do at the landfill?
47. Lastly, if you were given a choice between continuing to work at the landfill and using a bicycle to collection recyclables from households, what will you go for and why?

THANK YOU VERY MUCH FOR YOUR TIME AND WILLINGNESS TO BE A PART OF OUR PILOT PROGRAM, WE HIGHLY APPRECIATE IT!

NOTE: ON MONDAY WE ARE PLANNING TO DO A SIMILAR ACTIVITY IN WINDHOEK NORTH, EXCEPT THIS ENTAILS SORTING THROUGH THE BINS, WOULD YOU STILL BE INTERESTED TO ASSIST US?

TIME: 05H00
TRANSPORT: PROVIDED
PAYMENT: N$300.00

Appendix M: Interview with Formal Waste Collectors

M-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with the formal waste collectors in the city of Windhoek in order to fully understand how the current system of collecting waste is operated. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

M-2 Questions for Rent-A-Drum Truck Operator

Interview was conducted on April 24th, 2014.

Interview was conducted in the car as the Rent-A-Drum driver showed us the routes around the Polytechnic of Namibia which they collect from on Thursday afternoons.

Questions:

1. Which streets do you collect from?
2. How many people work with you on one truck for collection?
3. What are the different roles that each worker fulfills?
4. How much material/ how many bags do you usually collect from each house?
5. Is it always the same houses that put out bags?
6. Do some houses only put out the bags on certain weeks and then not on other weeks?
7. How long does it usually take you to collect the bags from this area?
8. How many streets do you usually collect from on a full day?
9. How many bags do you usually collect on a normal day?
10. Do you ever fill up the truck and have to go drop off before continuing with all the streets?
11. If yes, how often and where do you go to drop off?
12. Do any informal waste collectors ever cause you trouble or interfere with your work?
13. If yes, please explain how?

Appendix N: Interview with Residents of Pilot Neighborhoods

N-1 Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with the residents of the streets which we are collecting from in order to gain your opinion on our study. We are working on a project through the Polytechnic of Namibia which involves developing alternative methods for recyclable collection in Windhoek. Our ultimate goal is to design a program which employs informal waste collectors to utilize bicycles as a means of supplementing recyclable collection by truck and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

N-2 Questions for residents who live on the streets where we conducted the pilot study

Interviews were conducted on April 28th, 2014.

Interview was conducted outside the home of the resident.

Questions:

1. What do you think about our proposed idea?
2. Would you have any problems with someone sorting through your city of Windhoek wheelie bins?
3. What time do you usually put out your bins for collection?
4. Is there a reason you do not recycle?
5. Would you consider participating in the Rent-A-Drum clear bag system if they collected from this neighborhood?

Appendix O: Cart Attachment Instructions Manual for Manufacturing

Parts List

- 25mm Steel Pipe: 27.5m
- 40mm Angle Iron: 1.2m
- #16 Hex Nut: 1
- Cans of Rust-Proofing Spray Paint: 2
- Custom Canvas Bag (2mx0.8mx0.8m)
- Nylon Rope: 20m

Manufacturing the Cart Attachment

Step 1: Measuring and Marking Pipes

For this step you will need a tape measure and a permanent marker. Take the tape measure and measure 0.3m from one end of the pipe and mark that length with a permanent marker line around the pipe. Repeat this step with each of the lengths shown in Table 7 below. Once the pipes have been marked, repeat this with the angle iron with the lengths shown in Table 7.

Type of Material	Length (m)	Quantity
25mm Steel Pipe	0.4	1
25mm Steel Pipe	0.7	1
25mm Steel Pipe	0.75	2
25mm Steel Pipe	0.8	4
25mm Steel Pipe	0.83	1
25mm Steel Pipe	1.08	2
25mm Steel Pipe	2.17	1
25mm Steel Pipe	4	2
25mm Steel Pipe	6	1
40mm Angle Iron	0.3	4
40mm Angle Iron	0.1	2
40mm Angle Iron	0.05	2

Table 7: List of pipe cuts for the assembly

Step 2: Cutting the Pipes

Once the pipes have been marked, cut them along the marked lines. This should be done with a horizontal band saw (a hacksaw may be used if a band saw is unavailable). Place the pipe in the vice clamps of the saw and line up the marker line with the saw blade as shown in Figure 31 below.

Figure 31: Cutting pipe with a band saw

Once the pipe is properly lined up with the saw, turn on the saw and cut through the pipe, being careful to not shift the pipe in the process (make sure the vice clamp is tight to ensure that the pipes will not move). Repeat this step for each of the markings you made in Step 1. Once the pipes are cut, the 3m and 6m sections must be further marked. On the 3m pipes, mark 1m down from one side, to later be used for the pipe bending. On the 6m pipe, from one side mark down 0.8m, then 2m down from that, and then 0.8m down from that. This should result in the pipe having lines at 0.8m, 2.8m and 3.6m.

Next you will cut the angle iron. The process is the same except for the original clamping of the metal. Make sure that the angle iron is in the clamp with the right angle corner facing up (it should make a triangle with the bottom of the clamp) as shown in Figure 32 below. The angle iron is much thicker than the steel pipe and will take longer to cut through.

Figure 32: Cutting angle iron with a band saw

Once the pipes and angle iron are cut, the excess pipe will be cut into caps. Caps will be explained in Step 14. In order to make the caps, you will need eleven pieces of the excess steel pipe, each one between 25mm and 30mm long.

Step 3: Cleaning and preparing the pipes

For this step you are going to need a roll of paper towels. Each pipe must be cleaned to remove any surface rust that could get in the way during the assembly. Begin thoroughly cleaning each pipe by rubbing them with dry paper towels, as shown in Figure 33 below.

Figure 33: Cleaning pipes with paper towels

Once the pipes have had most of their surface rust removed, the areas that are to be welded must be further cleaned. Bring the pipes to an angle grinder that has a metal bristle brush head attached to it. The end of each pipe must be polished completely until it shines, as shown in the Figure 34 below. Clean approximately the last 20mm of each end of each pipe. The marks that were added after cutting the pipe must also be polished, approximately 20mm in each direction from the line. Then the measurement line must be redrawn, because these areas also come into contact with the welder.

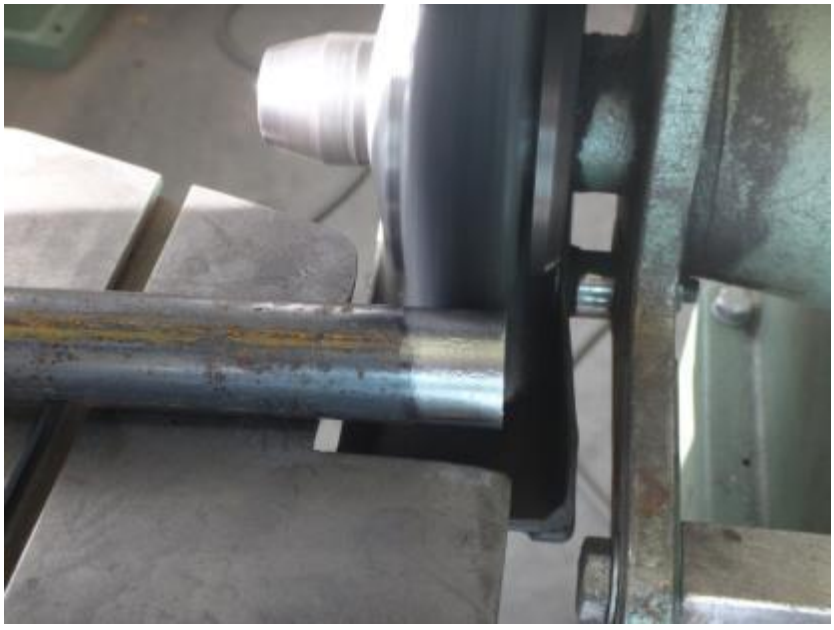

Figure 34: Polishing the steel pipes

You will also need to use the polishing wheel to remove the galvanization from all of the hex nuts and bolts. Welding a galvanized piece of metal can be dangerous to your health, as it releases zinc, which is very harmful to breathe, into the air. One at a time, use a set of vice grips

to strongly grasp a hex nut or bolt, and polish off the outer coating. The metal should look much duller if the galvanization is removed, as shown in Figure 35 below. The nut on the left is galvanized and the nut on the right has had the galvanization removed.

Figure 35: Hex nuts galvanized (left) and de-galvanized (right)

Step 4: Bending the Pipes

3 of the pipes you have cut must now be bent into shape. Take one of the 3m long pipes to the pipe bender, and place it in the turning mechanism. Make sure to line up the mark you made at the 1m point with the notch in the turning mechanism, as shown in Figure 36 below.

Figure 36: Lining up the pipe with the bender

Once the pipe is lined up, set the pipe bender for a 95° bend (the metal is slightly springy and will flex back to 90° when released). Slowly run the pipe bender until the bend is complete. Then release the pipe from the turning mechanism. Repeat this step with the other 3m pipe, to make two identical pipes. A picture of the pipe bending is shown in Figure 37 below.

Figure 37: Bending pipe

For the 6m pipe, repeat the 95° bend you made on the 3m pipe on the first mark of the 6m pipe. Once you have made that bend, you will need a level to make the other 3 bends. Slide the pipe through the turning mechanism until the next mark on the pipe is lined up with the notch on the turning mechanism. Use the level to ensure that the pipe sticking out of the end of the bender is level, which will ensure that all of the bends line up in the end. Repeat this step for the third bend in the pipe. Once the 3 bends have been made, the pipe should look like a rectangle with a small amount of pipe coming off of the non-bent corner. Cut this excess pipe off with the band saw to make it a rectangle.

Step 5: Grinding the Pipes

In order to make stronger weld connections for the attachment, the ends of some pipes need to be shaped using a grinding wheel. Two pipes will need to be shaped so their ends are angled. The angled ends of the pipe will make it possible to sit flush on another pipe. Begin by taking the 0.4m pipe to the stone head on the grinding wheel. Once the wheel is turned on and spinning, slowly push the end of the pipe into the wheel, which will remove metal, until the end is at approximately a 45° angle. Repeat this process for the other end of the pipe, mirroring the angle so the final pipe looks like a trapezoid. Once the pipe is shaped, repeat the process on the 0.83m pipe.

Next you will need to shape the ends of other pipes into a U-shape to have them wrap around other pipes for better grip. Begin by taking one of the 0.8m pipes to the grinding wheel. Place the center of on end against the corner of the wheel so it begins to shape a V out of the metal, as shown in Figure 38 below.

Figure 38: Grinding a V shape into the metal

Once the metal is shaped like a V, use the grinding wheel to round it out, and try to shape the U so it is approximately as wide as the diameter of the steel pipe. Once this is done, the pipe should be able to rest against another pipe to create a large amount of surface contact between the two pipes. Repeat this for the other end of the pipe, the other three 0.8m pipes and one end of the 0.7m pipe.

Step 6: Milling the Angle Iron

In this next step, you will be using a milling machine to create channels in the angle iron for the wheels to fit into. Begin by clamping one of the pieces of 0.3m angle iron into the vice clamp on the mill, so one end of the metal sticks forward, as shown in the photo below.

Figure 39: Milling the wheel channels

Using the adjustment wheels on the machine, line up the drill bit with the center (.15m) mark on the angle iron, and adjust the height so approximately 10mm of the drill bit is below the metal. Lock the horizontal wheel so it cannot shift while the machine is running. Point the coolant hose at the drill bit, to stop the bit from overheating as it cuts the metal. Turn on the coolant first, then the drill itself. Once the metal is covered in coolant, slowly push forward with the mill, drilling out a channel in the metal until you have cut approximately 25mm deep. Repeat this process for the other three pieces of 0.3m angle iron, making sure to keep the channels the same depth and in the same position on the angle iron across the four pieces. This is very important for the wheels to sit evenly on the frame in the final assembly.

Step 7: Lining up the Initial Pieces for Welding

The assembly of the pipes is based on three initial rectangles that will be made first and later put together with the rest of the pipes. The first rectangle is the easiest, as it is already made. In Step 4 you made a rectangle out of the piece of 6m steel pipe. Make sure all of the bends are even and the pipe is shaped correctly, so the end of the 2m section is touching the side of the end of the 0.8m section. This is your first rectangle, and will become the top of the cart.

Next, take the two 3m pipes you bent into L shapes. Lay them down and have them face in a way that they form a rectangle, with one side being 3m and the other being 1m long. Use multiple vice clamps to connect one corner together, making sure it has a strong hold. This is important, because the pipes cannot shift away from each other while the rectangle is being welded together. These two pipes will be your second rectangle, and will become the bottom frame of the cart.

For the last rectangle, you will need the two 0.75m and the two 1.08m pipes. Lay the two 1.08m pipes down so they are parallel and approximately 0.75m away from each other. The

0.75m pipes should then be laid on top of the other two pipes, so they line up end to end, and sit on top of the 1.08m pipes. Be careful to line up the pipes correctly, so they form right angles in each corner. Use vice clamps to clamp three of the corners tightly, the fourth corner will be welded first. This will form your third and final rectangle.

Step 8: Welding the Initial Rectangles

For Steps 8 and 9, welding experience is required. The initial prototype was built using oxy-acetylene welding, but stick welding is also a good option. Use whichever welding process you are more comfortable with. We will begin with the easiest weld, and work towards the harder welds in the end.

Begin by taking the 6m pipe that was bent into a rectangle. Make two small tack welds onto the non-bent end of the pipe, as shown in Figure 40 below. Make sure not to make too big of a tack, as you may need to bend the pipes at the welds in the end.

Figure 40: Welding a tack for a joint

Next, you will repeat the process with the two 3m pipes that were formed into a rectangle. Start by tacking the end of the pipes that do not have clamps on them, making sure the right angle does no shift during the welding. Once that weld is set and slightly cooled, remove the clamps from and tack the other side. The tack welds on the two ends should hold the rectangle together fairly well, but still be weak enough that they can be bent if need be.

The final rectangle is going to be the hardest to weld accurately, as it has no bends to create perfect right angles from the beginning. Tack the corner without vice clamps first, making sure to keep the pipes properly lined up. Once the first corner is tacked, move to the opposite corner, remove the vice clamps, and tack it next. This will help with some stability with the shape when creating the other welds. The order does not matter for the other two corners; do whichever is easier to line up first. While welding, ensure all of the corners remain lined up and are as close as possible to right angles. Once this is finished, you should have your third rectangle made of four pipes tacked together.

Step 9: Lining Up and Welding the Supporting Pipes

Once you have made the three rectangles, they will be put together with supporting pipes to become the cart attachment. Begin by attaching the diagonal support to the bottom rectangle of the cart. The rectangle made of two 3m pipes needs another support, as is will be bearing most of the weight the cart holds. Take the 2.17m pipe and fit it between the two welded corners of the rectangle. Tack the two ends of the pipes into the corners, which should fit correctly if the other pipes are correctly shaped. If the pipe is too big, grind down one end slightly until it fits. If it is too small, use extra filler material to fill any gap.

Next you will combine the two large rectangles together with vertical pipes to create the holding area of the cart. Start by taking the rectangle with the diagonal support and placing it on your work table or the ground. Next, take the four 0.8m pipes that you shaped the ends of and begin to line them up with the corners of the rectangle. The pipes will not fit perfectly in the corners and should be offset. Figure 41 below shows how the pipes should line up in the welded corners and in the bent corners.

Figure 41: Pipe offset for a bent corner and a welded corner

The pipes now have to be lined up with the other large rectangle, which is going to become the top of the cart. Place the top rectangle on top of the four supports, while having others hold the vertical pipes in place. The top rectangle is going to be longer than the bottom rectangle. Line up one of the shorter ends on each rectangle and the other side of the top should stick out. This will not be a problem. The area that sticks out past the end of the bottom will become the front of the cart. Once the pipes have been lined up correctly, clamp down seven of the eight points of connection with vice clamps, to ensure that nothing will shift during the welding. The non-clamped corner should be on the top rectangle.

Begin by tack welding the joint that does not have a clamp. Then one at a time move around the top of the rectangle tacking the other three connections. Once the top connections are all tacked, repeat the process with the connection points on the bottom.

Step 10: Attaching the Wheel Support

The third rectangle you tacked together in step 8 was the support for the wheels of the cart. This will now be attached to the center of the bottom of the cart, and create the spots for the wheels to slide into.

Turn the cart you tacked together in step 9 upside down, so the bottom of the cart is now facing up. Place the third rectangle so the 1.08m pipes are parallel to the short ends of the rectangle and center it along the length of the 2m section. The two 0.75m pipes should be underneath the 1.08m pipe so they sit on the same level as the pipes that the rectangle is resting on, as shown in Figure 42 below.

Figure 42: Wheel pipe alignment

If the rectangle is centered correctly, there should be gaps between the pipes that are approximately 0.11m wide, which is the gap for each of the wheels. Tack the rectangle across the four points of contact on the main cart, and along the two connection points on the diagonal support.

Step 11: Attaching the Wheel Channels

For this step you will need the two wheels for the cart, the angle iron you milled channels into, and the cart frame itself. Take one of the wheels and attach the angle iron to the area where a bicycle fork normally connects. The angle iron should stick out of the side, and the 0.3m length should be parallel to the ground. Place the angle iron on the other side of the wheel, which will result in two flat surfaces coming off of the wheels. Take the wheel with the attached angle iron, flip it upside down, and place it on the cart. The flat parts of the angle iron should sit on the pipes on either side of the gap you made for the wheels in Step 10. Repeat the angle iron attachment and wheel alignment with the other wheel.

Make sure the wheels are both aligned properly. The wheels should be centered in the gap with the angle iron centered along the pipes on which it sits. Take vice clamps and secure the angle iron to the frame, making sure they are tight enough that the metal cannot shift, as shown in Figure 43 below.

Figure 43: Clamping the wheel angle iron

Once the angle iron has been secured, loosen the bolts on the wheels and carefully slide them out of the angle iron channels, making sure not to shift the angle iron. It is important that the wheels are removed, as the tack welding could heat up and damage the wheels. Using the welder, tack the four pieces of angle iron into place. Remove the clamps and add more tacks in their place, making sure these are strong enough that the angle iron will not break off.

Step 12: Adjusting the Tacked Frame and Strengthening the Welds

At this point, all of the pipes of the frame are connected, except for the three that make up the connection to the bicycle. The next step is to make sure the entire frame is properly aligned and strengthen all of the welds. Take the frame and place it on the floor so the wheel angle iron is touching the ground. Carefully inspect the frame to make sure all of the pipes are at right angles to each other and that the frame is not leaning in any direction. If you notice that the frame is leaning at all, apply pressure to realign the pipes until it sits correctly.

Now that the frame is properly aligned, it is time to strengthen the welds on the entire structure. One joint at a time, add more filler rod to each connection, completely joining the two pipes to make a much stronger connection. Do not worry about pipes that have open ends, caps will be attached later to seal any pipes. Continue to move around the frame, until every connection is strengthened, including the angle iron for the wheels. For the angle iron, be careful

not to have any filler rod fall into the channels for the wheels, as this will not allow the wheels to properly fit into place.

Step 13: Attaching the Connection Pipes

The last pieces of pipe that need to be attached to the frame are the pipes that make up the connection between the cart and the bicycle. The first step is to attach the connection hex nut to the main pipe of this section. Take the 0.7m pipe, and secure it in a vice grip so one of the open ends is pointing up. Take one of the #16 hex nuts you removed the galvanization from and place the nut over the opening of the pipe so the threaded hole is centered. This should make the metal of the hex nut evenly line up with the edges of the pipe. Using less heat than you have in the past steps, weld the nut onto the pipe at each of the six faces of the nut. Be careful not to use high heat, if the nut is heated too much the threads can warp and a properly sized bolt will not fit correctly. This weld will not change in any later steps, so it should be welded all of the way around, not just tacked into place.

The next step is to attach the main support of the connection pipes to the frame. Take the 0.83m pipe that you shaped the ends of and line it up on the front of the frame. The pipe should run vertically in the center of the horizontal pipes on the front, creating a vertical pipe that sits in the center of the front of the cart.

Clamp this pipe in place once it is properly aligned, and tack it into place on the top and bottom of the pipe. Once the pipe is tacked into place and slightly cooled, step back and make sure it is properly aligned. If it is not, realign it by either bending the pipes or removing it and tacking it again. Once the pipe is properly aligned, strengthen the two welds that hold it onto the frame, so this pipe can no longer shift.

In order to connect the next pipe, you will need the bicycle you plan to use, along with the wheels for the cart and a level. Attach the wheels to the cart, but do not tighten them all of the way as they will be removed once this pipe is connected. Have the cart sit on the ground on its wheels and place the bicycle in front. Take the 0.7m pipe you welded the hex nut onto, and line up the shaped end of it with the pipe support you attached to the frame. This pipe needs to sit at such a height on that frame that the hex nut aligns with the bottom of the seat post while the cart is level. Have another person keep the cart level, while you line up the pipe and make a line on the frame with a marker to show where the bottom of the pipe should connect. Weld this pipe into place using the line you just made with the marker. Make sure this pipe is level with the rest of the frame when you weld it, so it sticks straight out off of the front of the cart. Again, you do not need to tack this pipe first, just make a strong weld around the pipe.

Once that pipe has been connected, the last pipe is to be attached. Take the 0.4m pipe you shaped and place it on the frame so it touches both the top of the pipe with the hex nut and the vertical support pipe. This will be an added support for the connection joint to make sure it does not warp as large amounts of weight are added to the cart.

Step 14: Capping the Open Pipes

In Step 2 you cut eleven pieces of pipe approximately 30mm in length, which will now be used to cap the openings on the frame. Take the first cut of pipe and place it on an anvil or any strong and flat surface. Using a hammer, hit the pipe until it flattens out into a rectangle of metal, as shown in Figure 44 below.

Figure 44: Making a cap with the anvil

Repeat this for the other ten segments, until you have eleven flat rectangles of metal to be used as caps. These will now be used to cap the open pipes on the frame to prevent buildup of rust inside. Choose one of the open-ended pipes to start with and lay down the cart in a way that one of the open ended pipe is facing up. Lay the rectangle of steel down on top of the pipe so it entirely covers the opening. Use the welder to melt the metal and attach it to the opening so the end of the pipe is completely sealed shut. If there is not enough metal, use filler rod to fill in any gaps. Lining up and welding the cap is shown in Figure 45 below.

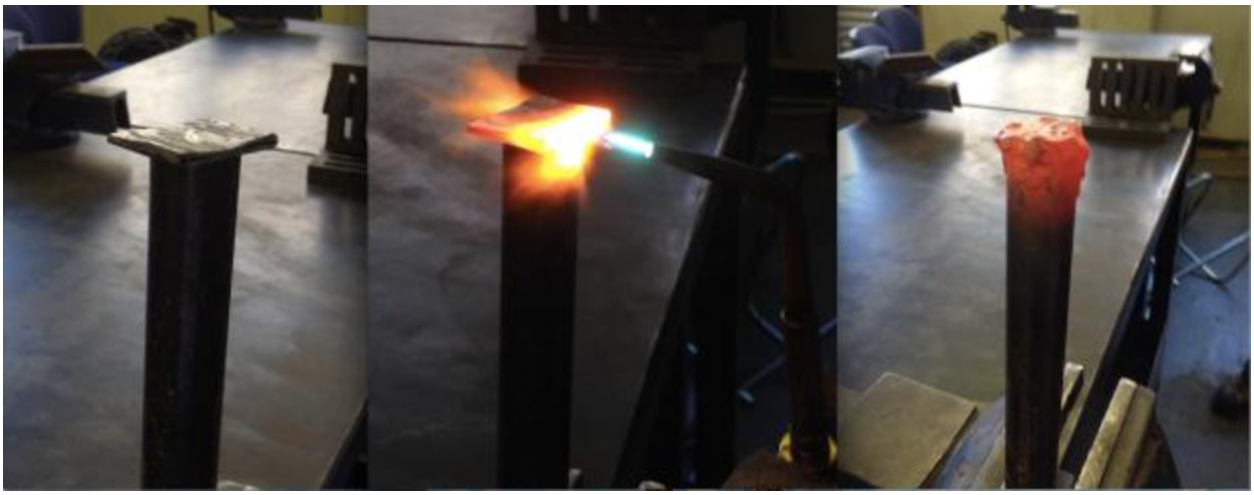

Figure 45: Cap alignment and cap welding

Repeat this process for the other ten openings on the frame. When this is done, the only opening on the cart should be the threaded hole of the hex nut. Look again over the entire frame and make sure there are not any other holes. If you find any holes, fill them in using filler rod. When this is done, the frame is sealed entirely and ready to be cleaned and coated.

Step 15: Cleaning and Painting the Cart

Now that the frame of the cart is entirely assembled, it is time to clean and prepare it for painting. Using the paper towel method from Step 3, clean the entire frame. On some parts of the frame there may be buildup of slag (waste byproducts that formed during the welding) that must be removed before the frame is painted. Slag looks grey and flakey and sits on top of the metal. Make sure the frame is entirely cleaned and free of rust.

Now that the frame is entirely cleaned, you will need the cans of rust-proofing spray paint. Paint the entire frame with the cans, making sure to coat evenly. Be careful not to paint the threads of the welded hex nut. Use a piece of tape to cover the opening if need be. Once the paint is dry, add another layer to ensure that the paint will not peel off easily.

Step 16: Stringing the Bag into Place and Attaching the Wheels

Now that the cart is completely formed and painted, the final step is to string the canvas bag into place. You will need two people to hold the bag in place while you weave the rope through. Begin by placing the bag in the frame and lining up the canvas edges with the corners of the cart. Starting at one corner, push the rope through the first islet in the bag and tie a simple knot onto the frame (this will be untied later). Weave the rope through the islets in a spiral pattern, making sure to go over and under the pipe between each islet, as shown in Figure 46 below.

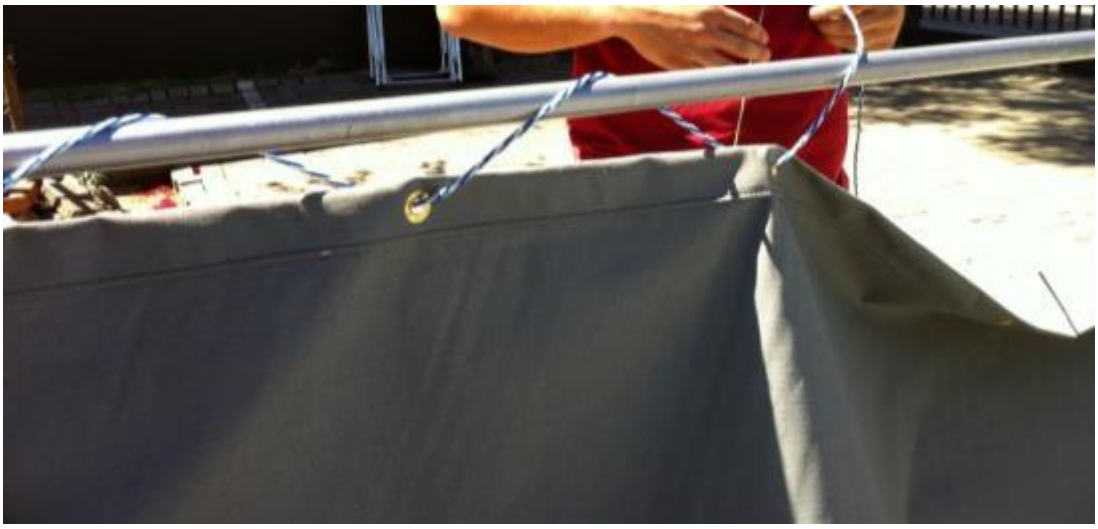

Figure 46: Spiral pattern for weaving the rope

After you have strung one side, you will come to a double islet that forms the corner. Put the rope through the first loop, thread it over the horizontal pipe, and wrap it around the vertical pipe. Go back over the horizontal pipe (which is now past the corner) and continue to weave the rope as you did for the first side. The corner should look like Figure 47 below.

Figure 47: Corner weaving method

Repeat the weaving process around the whole bag, making sure to go around all of the pipes and through each islet. Once the rope is through all of the islets, pull the slack through and make the rope tight around the frame. Once this is done, undo the initial know you made and make a strong knot with the two ends of the rope. When finished, the cart should look like Figure 48 below.

Figure 48: Weaving pattern for 3/4 of the cart

The final step is to make a barrier with the rope that prevents the bag from rubbing against the wheels. There should be two to four islets that are on the pipes over the area where the wheel sits. Place another piece of rope through the first of these islets, go under the bag, and put the rope through the same islet on the other side of the cart. Weave back and forth with this method, making U-shaped loops of rope that go under the bag until you are at the first islet on either side past the wheels. Slightly tighten these ropes enough that the bag's left to right motion is constricted. Tie off the rope so it cannot easily come undone, as shown in Figure 49 below.

Figure 49: Final knot for the rope

When the bag is fully attached, flip the cart upside down again. The wheels should still fit perfectly into the channels you cut into the angle iron. Put the first wheel into its channels, and make sure it sits correctly, without leaning in any way. Use a #15 head on a socket wrench or an

adjustable wrench to tighten the nuts on either side of the wheel. Make sure to tighten both evenly, going back and forth between the two, or else the wheel will end up leaning towards or away from the cart. Make sure the nuts are tight so the wheels cannot fall out. Repeat this for the other wheel.

This completes the instructions for the cart attachment. The next section will explain how to build the universal joint.

Appendix P: Universal Joint Assembly Instructions Manual

The universal joint is capable of connecting to any bicycle by attaching to the seat post. It is important to note that for the cart to be compatable with the joint, we welded a 16mm nut on the end of the pipe used for joining to the seat post.

There are eight parts to the universal joint; three of them are standard 10 mm bolts. The other 5 parts were to be made with stock angle iron along with 16 and 10 mm nuts and bolts.

Figure 50: The joint broken down in to its 8 components, left to right, 3-10 mm bolts, clamping plate for seat post, the stock, the pin, welded nut connecter, welded bolt connecter.

The use of left over angle iron along with simple nuts and bolts from the hardware store made this design very low cost and easy to build.

Parts List

- 40mm Angle Iron: 0.3m
- #16 Hex Nut: 1
- #16 Bolt at 50mm Length: 2
- #10 Hex Nut: 11
- #10 Bolt at 40mm Length: 5
- Cans of Rust-Proofing Spray Paint: 1

Manufacturing the Universal Joint

Step 1: Cutting the Angle Iron

The first thing you will need to do is cut the pieces of angle iron that will make up your main section of the universal joint. Using the method from Step 3 in the cart assembly, cut two pieces measuring 100mm and two pieces measuring 50mm. The cuts do not have to be exact, but it is important that the pairs of metal are the same length.

Step 2: Milling the Angle Iron

Next, you will need to mill the angle iron down to size. Put the 100mm piece of angle iron into the mill as you did in Step 6. This time, you will be leaving the vertical and front-to-back adjustments the same and slide the part left to right under the drill bit. Remove

approximately 15mm from one side of the angle iron, as shown in Figure 51 below. Leave the other side of the angle iron at its original length. Repeat this with the other piece of 100mm angle iron. In the end the angle iron should be approximately 25mm and 40mm on the sides

Figure 51: Milling the angle iron

Next you will remove the same amount of material from the 50mm pieces of angle iron. However, you will remove the 15mm from both sides of both pieces of 50mm, making it 25mm on each side.

Step 3: Cleaning/Grinding the Nuts and Bolts

Next you will need to remove the galvanization from all of the hex nuts and bolts you are going to weld. Using the same process from Step 3 of the cart assembly, remove the galvanization from the other #16 hex nut first. Next, remove the galvanization from ten of the eleven #10 hex nuts. Repeat this process for the two #16 bolts and for two of the #10 bolts.

Step 4: Cutting the Bolts

For one of the #10 bolts, you will also need to remove its head. Place the threaded section of the bolt in a vice clamp, so the head of the bolt is sticking out. Cut the head off of the bolt using a hacksaw.

Next you will need to cut the two #16 bolts down to a shorter length. Using the hack saw, cut the two #16 bolts down to a length of 35mm on the threaded section. Be careful not to damage the threads that are not being cut off, as this can lead to the bolt getting stuck when the joint is finally assembled.

Figure 52: Cutting the bolts with a band saw

Step 5: Removing the Threads of the Hex Nuts

For this joint, seven of the ten #10 hex nuts will need to have their threads drilled out. This can be done with either a drill press or a hand drill, but a drill press will be much easier. You will need a #11 drill bit, which is just big enough to remove the threads and a small amount of material from a #10 hex nut. Make sure the drill is centered on the hex nut, and slowly push the drill down to drill out the threads, as shown in Figure 53. Repeat this for six more of the nuts, making seven nuts that no longer have threads in them.

Figure 53: Drilling the threads out of the hex nut

Step 6: Making the Initial Welds

In order to assemble this universal joint, you will need to weld in steps, slowly combining parts until you have the completed joint. The first pieces you are going to combine are the two pieces of 100mm long angle iron. The two pieces should be put together to create a rectangle, as shown in Figure 54 below. Weld along the edges of the two pieces, to combine the pieces into a single rectangular prism with a hollow middle.

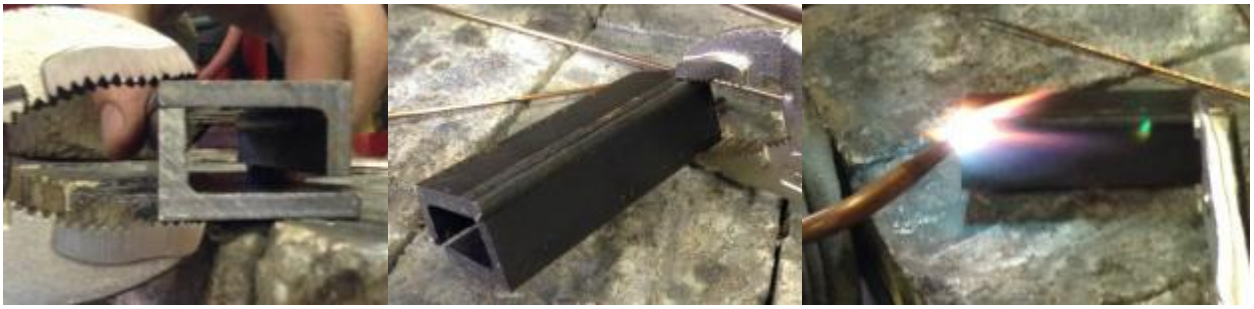

Figure 54: Clamping and welding the rectangle

The next step is to combine some of the hex nuts. Take two of the de-threaded #10 hex nuts and place them on top of each other, so their holes are aligned. Using a very small amount of filler rod, attach the two nuts together. Once this is cooled, it will be attached to the #16 hex nut. One side of the #16 nut should be touching both of the #10 hex nuts, so the holes are perpendicular, as shown in Figure 55 below. Weld these nuts together now, making sure not to heat up the #16 nut too much, otherwise the threads may warp.

Figure 55: Welding together three hex nuts

The next step is to weld the two #16 bolts you cut together. The bolts need to be pointing in two different directions, perpendicular to each other. Take one bolt and place it in the vice clamp so the head it facing up. The other bolt needs to be laid so one of the six sides of its head is lying flat on the top of the other bolts head, as shown in Figure 56 below.

Figure 56: Two#16 bolts welded together

Weld this connection, making sure the connection is strong. This two bolt piece is the main source of rotation for the joint.

The last initial weld is combining the two #10 bolts that you removed the galvanization from. These will become the pin for the joint. Attach the bolt that you cut the head off of to the end of the other bolt using the welder, making one longer bolt. It does not matter that the threads in the middle will be lost; you will only be using the bottom 1/4 of the threads on the bolt.

Figure 57: Welded pin made from two bolts

Step 7: Welding Round 2

At this point, the rectangle made of angle iron should be cooled enough to work with again. Take one of the 50mm length pieces of angle iron, and place it so one flat section covers most of the opening of one end of the stock, as shown in Figure 58 below.

Figure 58: Welding the angle iron to the rectangle

The 50mm piece of angle iron needs to stick out slightly, as hex nuts will be welded onto its edge in a later step. Weld this piece of angle iron onto the rectangle you have already created, making sure to use filler rod around the entire connection to ensure it is strongly connected.

On the other end of the rectangle, you are going to weld two of the de-threaded hex nuts, which will be used to hold the pin in place. On the shorter ends of the rectangle you are going to weld a hex nut. One side of the hex nut should be aligned with the short side of the rectangle, with the hole pointing in the direction of the long side, as shown in Figure 59 below.

Figure 59: Hex nuts welded to the rectangle

Weld this nut into place; ensuring the weld is strong. Repeat this with the second nut on the other short edge of the rectangle, making two holes for the pin to slide through.

Step 8: Welding the Final Hex Nuts into Place

The last step is to attach the other hex nuts into place. You should have three threaded and three de-threaded hex nuts, all of which have their galvanization removed. There is one galvanized hex nut left, which will be used to hold the pin in place. You need to separate the six de-galvanized pins into three pairs, each of which has a threaded and de-threaded nut. These pairs will become the three spots where the other #10 bolts connect and make a grip for the bicycle seat post.

Begin by laying down the angle iron rectangle so the smaller piece of angle iron is touching the surface of your work area. Place one threaded hex nut on one edge of the angle iron and one de-threaded nut on the same side of the angle iron, but farther down, as shown in Figure 60 below.

Figure 60: Lining up the hex nuts on the angle iron

Weld these two nuts into place, being careful to keep the heat of the torch low to prevent the warping of the threads on the nut. Place one threaded nut on the other edge of the same angle iron and weld it into place, as shown in Figure 61 below.

Figure 61: Lining up the third hex nut

The next step is to align the other hex nuts on the small piece of angle iron that is not attached to anything. This piece will become the other half of the grip for the seat post. Take the three galvanized #10 bolts and attach the bolts to the nuts and the stock, the de-threaded nut should be first on the bolt, and the threaded nut should be on the end. Line up the nuts on the other piece of angle iron, and mark their positions with a marker. Remove the bolts and line up the three free nuts with the three lines on the angle iron. The nuts need to be the opposite of their counterpart on the other piece (a de-threaded and a threaded should line up). Weld these in place, being careful not to warp the threads. Once these are welded, you have completed the assembly of the joint. Figure 62 below shows the operation of the three bolts and nut system clamping onto the seat post.

Figure 62: Angle iron properly lined up

Step 9: Cleaning and Painting the Joint Assembly

Now that the joint is entire frame is assembled you will need to clean the joint to prepare it for painting. From the welding there will be a buildup of slag on each piece of the assembly. Using the metal brush head on a grinding wheel, polish each of the pieces one at a time until you are sure that all of the steel surfaces are clean.

Once the pipes are cleaned, you will need to paint each of the individual pieces. Use pieces of tape to cover any threads on all of the bolts and the inside of the threaded nuts. Once the threads are covered, spray paint each piece with the rustproofing paint, making sure to cover the entire joint. A second coat of paint should be added to ensure that the paint does not easily chip off. Once the paint is dry, remove the tape from the threads and coat them with a metal lubricant or rust remover, which will ensure that the joint moves fluidly in all directions. Put the

pieces together, and create the final joint. Pictures of the final joint attached to the bicycle are shown in Figure 63 below.

Figure 63: The assembled universal joint painted and connecting the cart to the bicycle

Appendix Q: Sustainable Urban Transport Master Plan 2013

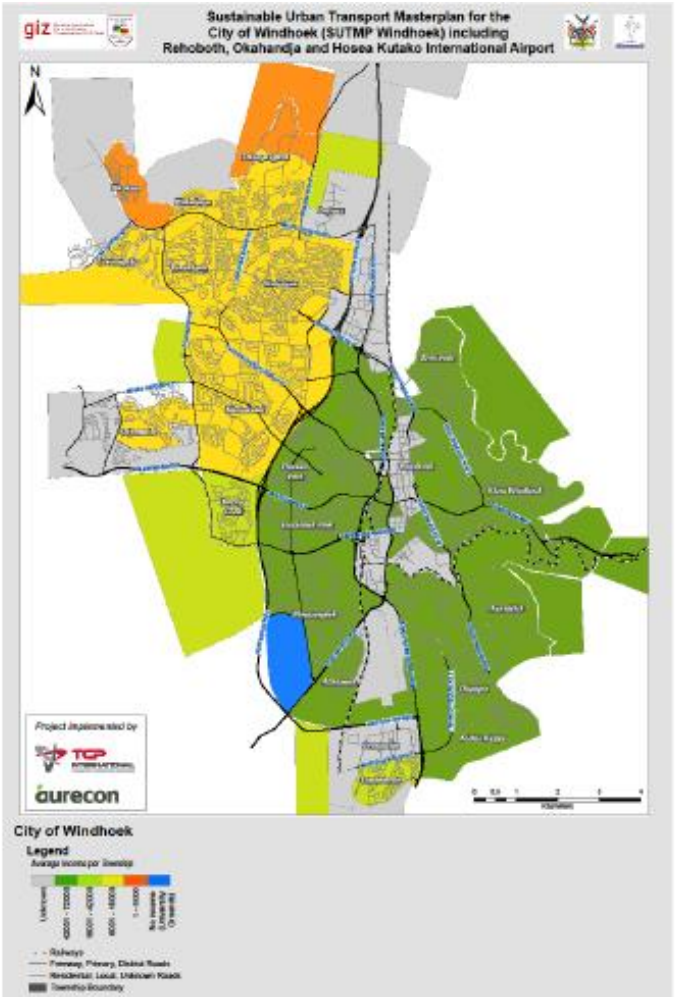

Figure 64: Average income distribution in Windhoek, map: Sustainable Urban Master Transport Plan 2013

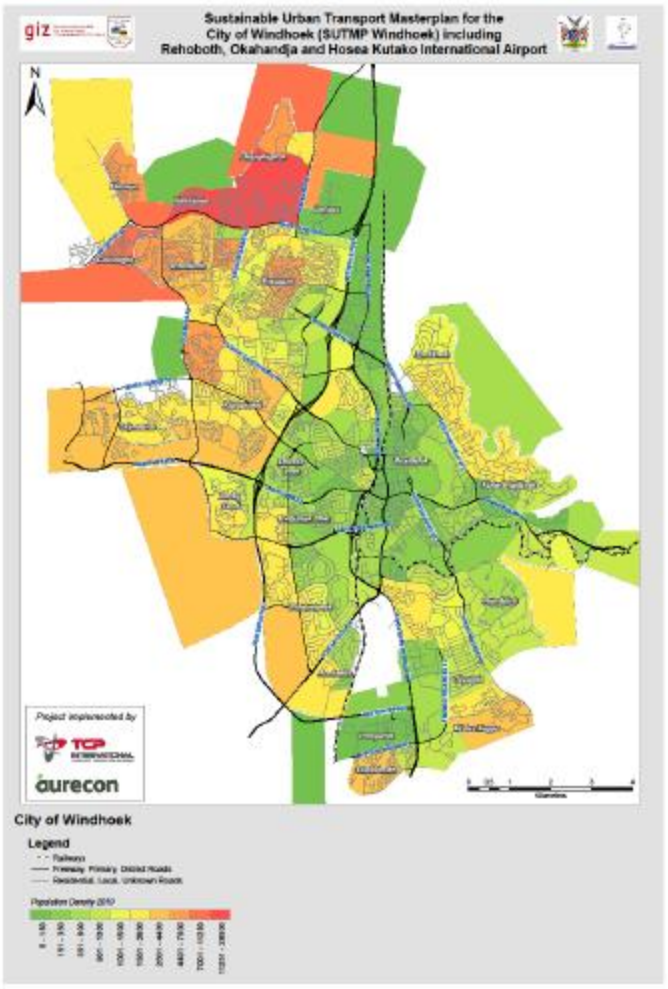

Figure 65: Population density in Windhoek, map: Sustainable Urban Master Transport Plan 2013

Figure 66: Mode of transport demand in Windhoek, chart: Sustainable Urban Master Transport Plan 2013

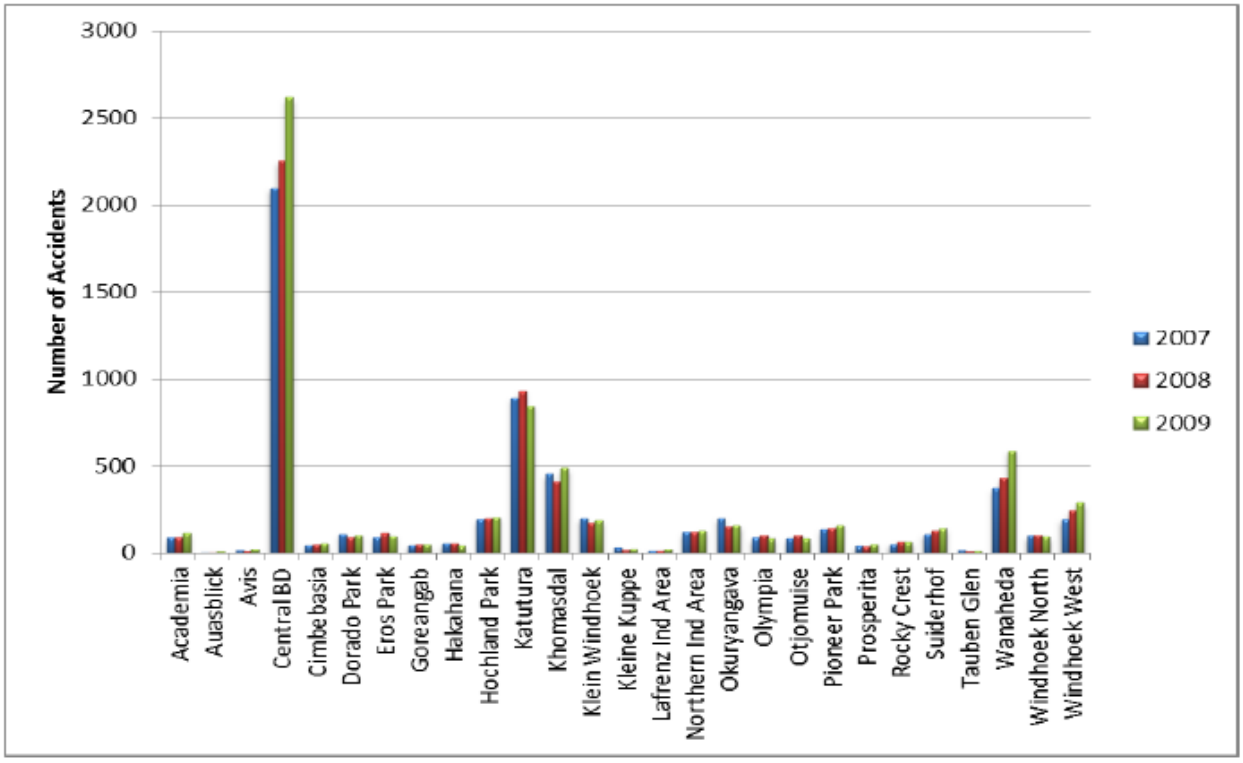

Figure 67: Number of accidents per year by suburb 2007 to 2009, table: Sustainable Urban Master Transport Plan 2013

Appendix R: Miscellaneous Pictures

Figure 68: Rent-A-Drum collecting recyclables from a recyclable separation receptacle

Figure 69: Interview of Rohan Louw at Rent-A-Drum

Figure 70: Rent-A-Drum's material recovery facility sorting line

Figure 71: Rent-A-Drum's material recovery facility baling area

Figure 72: Interview of Dieter Tolke at the Kupferberg Landfill

Figure 73: Kupferberg landfill general waste section

Figure 74: Helmut biking with the final cart

Figure 75: Sorting the collected recyclable materials

Figure 76: Collection through at-the-source separation

Figure 77: At-the-source separation

Figure 78: Emptying cart for sorting

Figure 79: Sorting materials into Rent-A-Drum bags for pick up

Figure 80: Informal waste collectors searching City of Windhoek bins for recyclables

Figure 81: Full bin from at-the-source separation

Appendix S: Rent-A-Drum Clear Bag Collection Pilot Trial Data

Table 8 below is a compilation of the data we collected during the Rent-A-Drum pilot trial. We recorded street names, number of houses, time lapse per house, number of bags, and other general comments and observations.

Drop-Off	Street	Time	# Bags in House	Comments
Run 1		9:00 AM		
1	Mozart	3:45	1	Need kickstand + chocks
2		5:20	2	Threw RAD bags into bin, downhill
3		6:10	1	
4		7:15	2	
5		8:00	2	1 non clear bag
6	Schubert	10:50	1	
7		11:30	1	Uphill is heavy, met resident, uphill
8	Beethoven	14:40	1	Bag clipping wheel, a little traffic
Drop Off		18:50		Often cars will not wait, drop off took 2 minutes
Run 2		23:15		Good amount of weight, water into bag
9	Wagner	23:54	1	
10		24:40	1	IWC Sighted, uphill
11	John Meinert	27:30	1	Complement from resident on bin
12		28:10	1	
13	Beethoven	29:40	1	
14		30:30	1	Turned back to John Meinert
15	John Meinert	31:55	1	A little traffic
16		32:30	1	Slight downhill grade
17	Strauss	35:10	1	Second complement on bin
18		36:30	1	
19		38:50	1	Flat grade
20		39:00	1	
21		39:50	1	Sudden uphill, walking bike
Drop Off		43:00		Drop off to 2 minutes
Run 3		46:15		Short water break, Helmut still happy
22	Roentgen	50:45	5	
23		52:40	2	Bag dragging a lot on wheel
24		54:50	1	Tough to balance with current kickstand
25		56:56	1	
26		57:45	1	

27		58:20	1	Walking back uphill, chain off
28		58:30	1	First busy intersection, 30 seconds to cross
Drop Off		1.08:00		Drop off took 2 and a half minutes
Run 4		1.19:30		Evan adding rope to prevent wheel contact
29	Simpson	1.24:00	1	
30	Curie	1.24:55	2	Flat slight downgrade, easy biking
31		1.26:52	1	
32		1.28:00	1	
33		1.28:55	1	Onto Back, Heavy traffic, uses dirt sidewalk
34	Jenner	1.36:12	1	Safely off main road, no problem
35		1.37:45	1	Downhill on best then walked up
36		1.40:00	2	Up Galen, car blind spot over hill
37	Galen	1.43:50	3	
38	Simpson	1.46:50	2	
39		1.48:75	2	
40		1.50:00	1	Cart very full, still okay
41		1:50:45	1	Up Beethoven, very slow, needed push help
Drop Off		1:58:30		Final drop off took 3 minutes
	Final time:	11:01 AM		

Table 8: Recording sheet from Rent-A-Drum collection

Table 9 below contains the weights of each clear bag collected in the four runs of the pilot trial.

Drop-Off	Bag Weight	Drop-Off2	Bag Weight3
1	8.9	3	7.15
	2.15		10.8
	3.3		4.3
	1.65		4.2
	4.65		12.5
	3.25		2.25
	2.65		0.75
	4.35		9.35
	2.8		5.7
	4.2		4.6
	4.8		1.1
2	3.3		3
	5.1	4	2.7

	1.75		8.3
	9.2		1.9
	2.05		1.8
	1.75		5
	1.5		3.65
	1.5		3.3
	0.9		2.95
	3.7		2.5
	0.8		6
	2.45		4.7
	1.6		3.7
	2.25		2.3
			2.2
			10.6
			5.55
			4.4
			1.95
			2.05

Table 9: Weight of each clear bag collected

Table 10 below shows the total number of bags collected in each run as well as the total weight of the bags collected.

Drop-Off	# of Bags	Weight
1	11	42.7
2	14	37.85
3	12	65.7
4	19	75.55
Total	56	221.8

Table 10: Total number of bags and weight collected in each run

Table 11 below contains the weights of the different recyclable materials collected, which we determined by sorting out the recyclables from the Rent-A-Drum clear bags. We have excluded the weight of waste materials we found mixed in the clear bags from this table.

Weight (kg)	1	2	3	4	5	6	7	8	9	10	11	12	Total
Glass Bottles	15	12.05	11.3	14.6	15	12.45	11.5	3.7					95.6
Plastic Bottles	1.2	4.4	2.15	3.25	2.4	1.65	1.75	3.7	3	1.3	1.75		26.55
Other Plastic	1.5	1.15	1.9	1.05	0.9	2.5	1.1	0.9					11
Boxes	1.8	1.45	2.3	2.25	0.3	0.6	2.75	0.8	3.05	1.15	2.3	1.9	20.65
Paper	6.2	3.8	11.6	3.8	4.1								29.5
Metal/Cans	4.3	3.2	2.65	1.55									11.7

Table 11: Weight of each bag collected after sorting by material

Appendix T: At-The-Source Sorting of Recyclable Materials Pilot Trial Data

Table 12 below is a compilation of the data we collected during the at-the-source pilot trial. We recorded street names, number of houses, time lapse per house, and other general comments and observations.

Column1	house #	Time in	Time out	Comments
Stephenson street	1	00.01.00	00.11.50	So far, fine, collecting decent amount. A little bit of trash on the ground but he picked it up using empty bags to put trash while taking out recyclables. 2 RAD bags
	2	00.12.30	00.17.30	Bottles on bottles. Helmut: one person fine, maybe two for emptying
	3	00.18.45	00.20.20	No cars yet, very little trash
	4	00.20.50	00.37.00	Told us about heat and rain at landfill, left a little trash at first. 2 bins
	5	00.37.30	00.40.00	just put bin out. Difficult to get all the way to the bottom
	6	00.40.10	00.47.00	2 bins, just put out (backtrack)
	7	00.47.45	00.52.30	Helmut believes this would work in Katutura, likes the flat terrain here better than Thursday
	8	00.53.15	00.55.50	stopped at black bag, he is picking up their trash
	9	00.56.20	01.03.40	maybe flipping the bin, I would wake up earlier like 4:00 AM, safety? It would be ok, take everything out then
	10	01.04.00	01.06.00	trying it his way, never mind, observed content and decided not to flip
	11	01.07.00	01.08.20	two trash bags, no bin
	12	01.10.00	01.25.10	Ouma always says paper and bottles are best. Helmut very accurately observes bin, he believes that at the landfill he can get more, these ones are more clean, during rainy season needs jacket, same as landfill, but RAD might still collect
	drop off	01.32.20	01.36.30	Turned back, walking up slight hill, more bins are out now, two people flipped cart and pushed out bag which worked perfectly. 3 houses had RAD bags
Sauer Strausse	13	01.37.30	01.42.30	Almost every street has people collecting bottles from the bins (only from the top layer) no interaction with us. Helmut is picking up whatever he drops
	14	1.43.00	01.49.00	so far, easier than Thursday, less cycling and more sorting time. Also not as heavy today. He would pick this one

				(pay aside). Trust issue!
	15	1.50.00	2.00.30	
	16	2.01.30	2.06.30	he mostly does not take plastic bags because he prefers "bigger plastics"
	17	2.07.00	2.13.45	if you were working all day you would take the plastics
	18	2.14.15	2.18.45	
	19	2.19.00	2.22.00	
	20	2.22.30	2.23.15	1 dirty old bin
	21	2.23.45	2.31.00	2 bins
	22	2.31.30	2.35.30	
	23	2.36.00	2.38.15	
	24	2.38.40	2.42.30	He seems to be getting more efficient already. Maybe a mask for smell
	25	2.43.15	2.49.30	
	26	2.50.30	2.53.15	
	27	2.53.45	2.55.30	
	28	2.56.00	3.00.10	huge mess on ground, cart full
	drop off	3.02.45	3.05.30	

Table 12: Data recording sheet from at-the-source collection

Tables 13 and 14 below contain the weights of the different recyclable materials collected from both runs, which we determined by sorting the recyclables Helmut brought to the drop-off location.

Drop-Off	Recyclable	Weight 1	2	3	4	5	6	Total
1	Glass Bottles	13.6	12.3	13.3				39.2
	Plastic Bottles	1.45	2.1	1.95				5.5
	Other Plastic	0.4						0.4
	Boxes	1.15	1	1.95	0.3	0.75	1.3	6.45
	Paper	11.2						11.2
	Metal/Cans	2.9	1.25					4.15

Table 13: Weights of materials collected from the first drop off

Drop-Off	Recyclable	Weight 1	2	3	4	5	6	Total
2	Glass Bottles	15.5						15.5
	Plastic Bottles	1.45	1.75	1.25	1.6	1.9		7.95
	Other Plastic	0						0
	Boxes	1.25	1.65	0.9	1.75	2.25		7.8
	Paper	15.5	6.75					22.25
	Metal/Cans	5.15						5.15

Table 14: Weights of materials collected from the second drop off

Drop-Off	Total Weight
1	66.9
2	58.65

Table 15: Total weight of materials collected in each collection run

Appendix U: Rent-A-Drum Truck Operational Costs

Table 16 below shows a rough estimate of what it would cost Rent-A-Drum to run one of their Kia flatbed trucks on the collection route which we completed in our first pilot test. The mileage of the truck was found from the Kia website for a flatbed truck similar to the ones which Rent-A-Drum uses for their collection. The total distance traveled was approximately 8km. From these numbers, and the current cost of diesel in Windhoek we calculated the cost of running the truck for the entirety of our route. These numbers are very rough estimates since the mileage found was for a similar truck, not necessarily for the exact trucks Rent-A-Drum uses. Another source of error is city driving versus driving on a highway and the different mileages achieved by the truck. The total found in Table 16 below is the best case scenario for this particular truck.

Total Route Distance (km)	Mileage (km/L)	Cost of Diesel (N$/L)
8	10.1	12.51
		Diesel Used in the Route (L)
		0.79
		Cost to Run the Route (N$)
		9.91

Table 16: Approximate fuel costs for a Rent-A-Drum truck on our collection route

Appendix V: SolidWorks drawing of final cart attachment frame

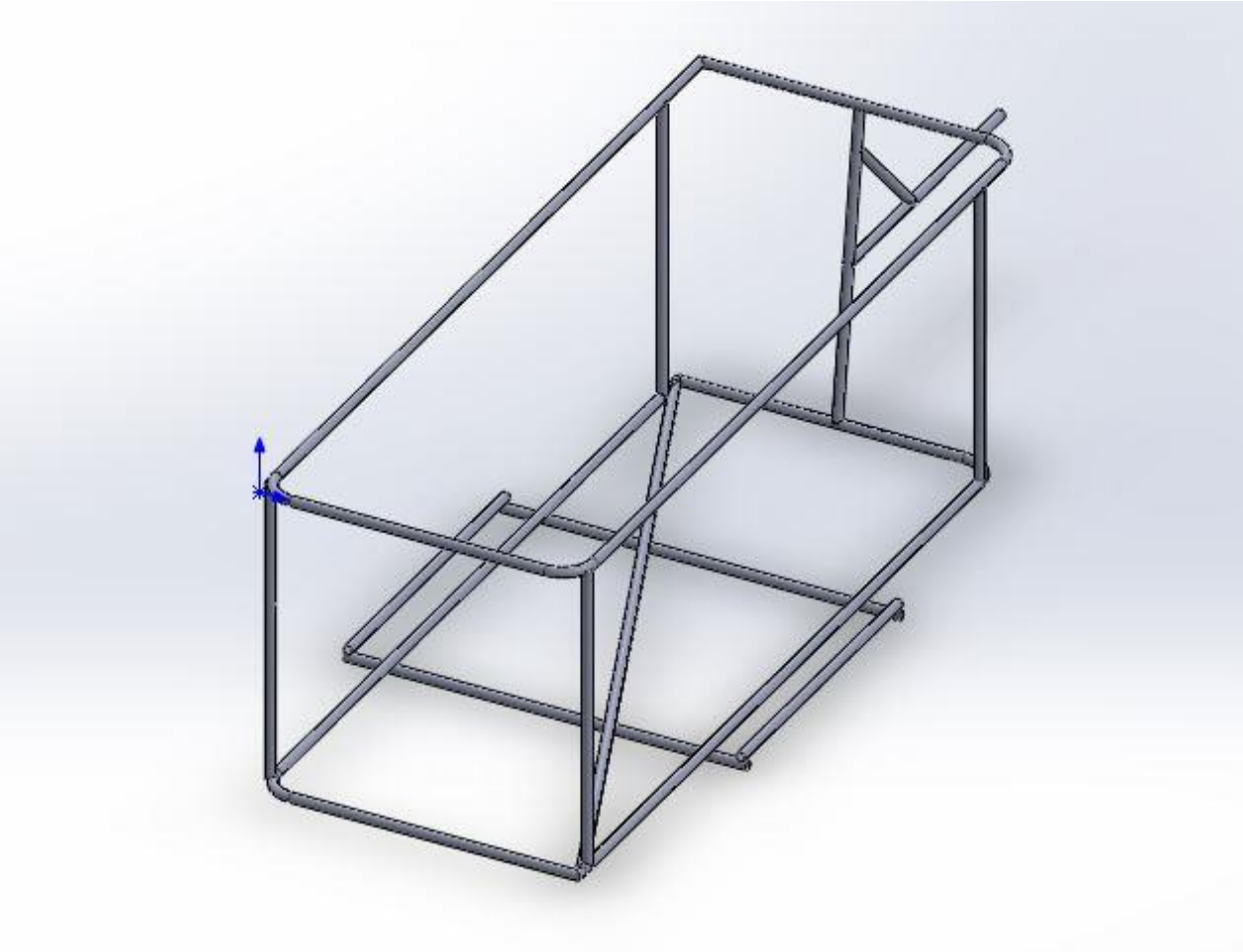

Figure 82: Final 3D view of cart attachment frame

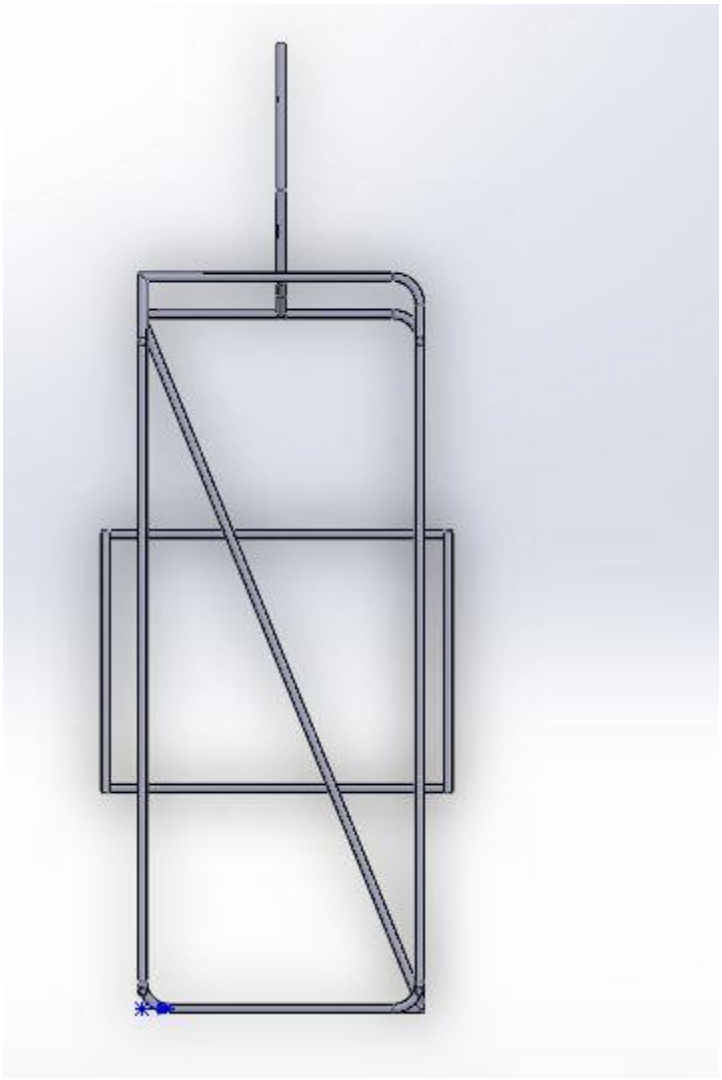

Figure 83: top view of the cart attachment frame

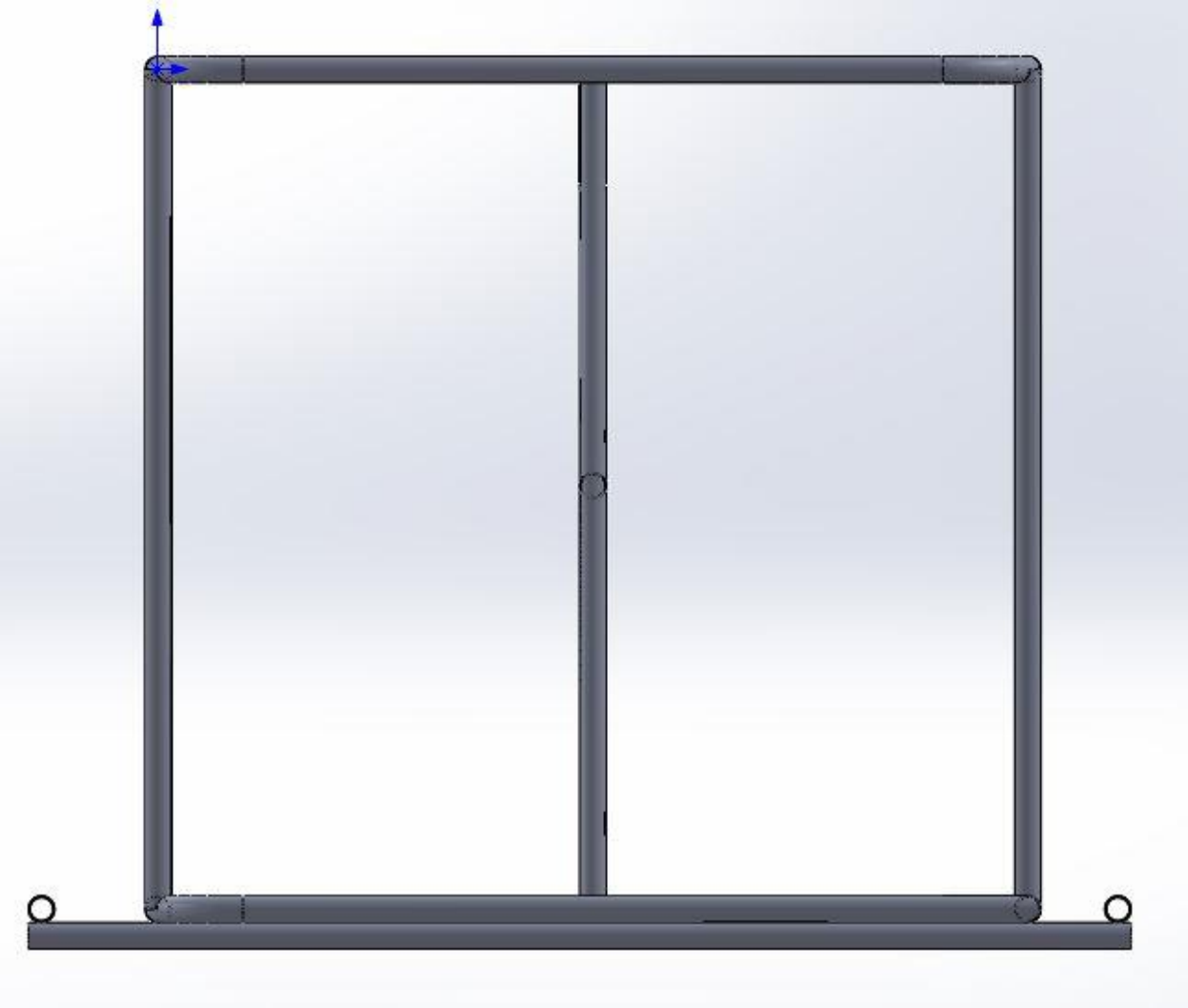

Figure 84: Front view of the cart attachment frame

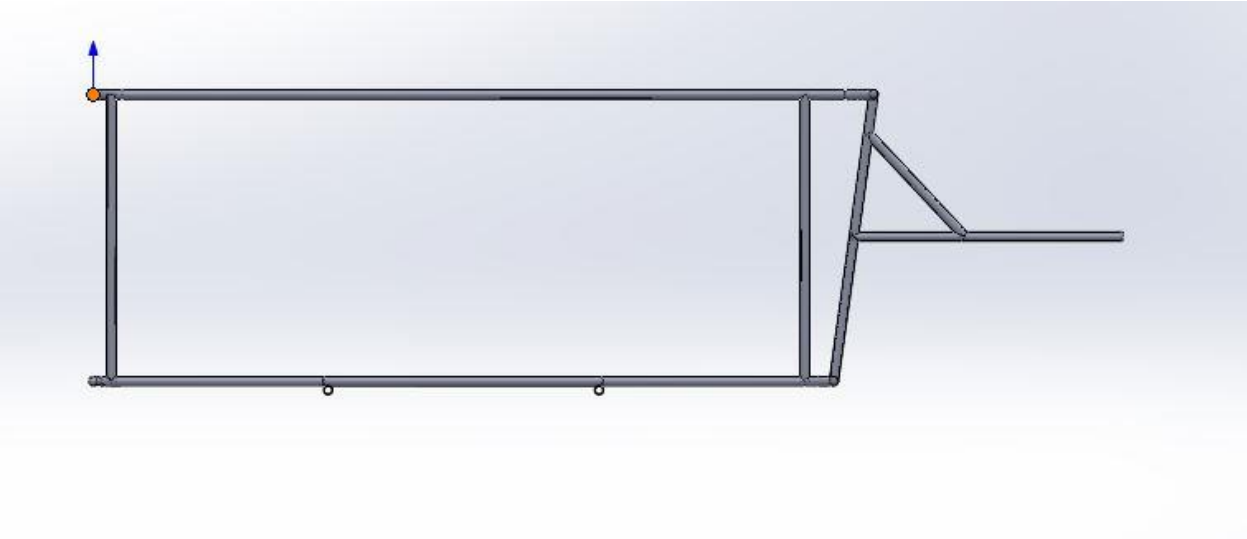

Figure 85: Side view of final cart attachment frame

Appendix W: Estimates of Rent-A-Drum Selling Prices

Recyclables Selling Prices		
Material	**Company**	**Price per Ton (NAD)**
Glass	Nampak Packaging Company	760
Cardboard	Extrupet	1050
Newspaper		900
White Paper		2100
Magazine Paper		750
Mixed Paper		700
Clear Plastic Bottles	MPact	3650
Brown Plastic Bottles		3000
Green Plastic Bottles		3800
HD Plastic Bottles		2500
Other Plastics	Namibia Polymer Recyclers	700
Metal Cans	Collect-A-Can	2000

Table 17: Baled and sorted recyclable prices