Developing A New and Sustainable Weight Estimation Method for Habitat for Humanity ReStore Metro-West/Greater Worcester and Beyond

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An Interactive Qualifying Project submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the degree of Bachelor of Science/Arts

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Abstract

Habitat for Humanity Metro-West/Greater Worcester needed a new method to estimate landfill diversion from their ReStore sales. The nonprofit uses diversion numbers to apply for grants that support them financially. We developed a methodology to find the average weight of inventory being purchased by customers. We compiled data by physically weighing items to create departmental averages. We created a calculator on Microsoft Excel to allow ReStores to calculate how many pounds of inventory they diverted from the landfill. We crafted training documentation on how to use and customize the calculator to each unique ReStore's needs. The results of our project are sustainable, simple, and customizable within the organization.

Executive Summary

Introduction:

Our project team was called to assist Habitat for Humanity Metro-West/Greater Worcester in revising their method of landfill tonnage diversion in their resale store, The Habitat for Humanity ReStore. A previous project team created a method for the organization, but data was lost, contained ambiguous assumptions, and the method was deemed not sustainable for the organization. The ReStores run by Habitat for Humanity are essential to the organization's efforts to keep the costs of building and renovating affordable homes in the community to a minimum. The proceeds from the ReStore directly fund the work of the organization.

Our team aimed to create a sustainable and simplistic method of weight estimation for Habitat for Humanity in order for the organization to accurately report item diversion from landfills. Landfill diversion metrics are significant to the organization as this number is reported when applying for grants to fund their mission. Our new method will now help Habitat generate a more precise metric. To begin our process, we conducted thorough background research to learn about the organization and topics in which our project brushes upon.

Background:

Habitat for Humanity is a nonprofit organization that has been working to solve the housing crisis since its foundation in 1985. Through the years, it has improved the lives of over 35 million people by constructing or rehabilitating over 70,000 dwellings (Habitat for Humanity, n.d.a). Habitat works with a diverse base of volunteers to solve the issues of housing insecurity by giving them a chance to help those in need in more than 70 countries. Volunteer work is the backbone of Habitat’s building operations, and makes building homes a rewarding experience not only for those who help build but also for the families helped by this organization. As they

work on the houses, volunteers learn about the fundamentals of building, strengthen their relationship with the community, and also grow emotionally attached to the families who will live in them.

Massachusetts has an alarming level of poverty and housing instability. In Worcester, Massachusetts, Studio apartments cost an average of $1,250 per month to rent, while one-bedroom apartments cost an average of $1,661 per month to rent (Woods, 2020). This makes it difficult for low-income individuals and families to find adequate housing and afford the additional expense of furnishing a new apartment or home.

Thankfully, Habitat for Humanity offers a remedy to these high furniture and houseware prices. The Habitat ReStore offers a frequently changing inventory of almost everything an apartment or house could need. Being a resale store, the prices of their products are incredibly reasonable and are usually 50-75% lower than retail values. Donations of lightly used items from the community and other organizations make it possible for Habitat to re-sell these items, funding their mission and keeping furniture from being thrown away.

Unwanted furniture, clothing, and other household items are usually disposed of, adding to the pre-existing problem of our overcrowded landfills. This is why resale stores like the Habitat ReStore are important to our environment. They support a sustainable model of economy, called circular economy, that focuses on eliminating waste, circulating products at their highest value, and regenerating nature (Ellen MacArthur Foundation, n.d). Companies that benefit from our traditional model of linear economy, a take-make-use-destroy design, are unable to make the switch to circular practices due to the lack of education, technological advance, and the absence of regulatory policies. However, the circular economy could save supply chain

companies up to $380 billion each year, if proper implementation was carried out (Govindan, 2018).

A project group in 2015 crafted a weight estimation method for Habitat for Humanity Metro-West/Greater Worcester (Daly, 2015). This team created two methodologies, one being a manually filled database to calculate the average weight of the items in each department of the ReStore. This average value was then multiplied by the total recorded sales from each department to determine the total weight of merchandise sold by each department at the end of every month. They also developed a conversion factor by creating a proportional relationship between the total price of items sold and the weight of those items, broken down by department such that each department receives its conversion factor. These methods were adequate for the ReStore for some time until the data and database structure were lost before it could be reimplemented or replicated later. This metric has been easy to use, but the organization lacks data to support its assumptions.

Methods:

To develop our methodology, We first volunteered in the Worcester ReStore to understand operations and workflow. The main takeaway from our volunteering was that average weights varied significantly between item departments and per-department sales distributions are not guaranteed to be static year-over-year, let alone between various ReStore locations. This meant we would need a per-department approach to account for weight variations and customer purchases.

Over the next several weeks, we tallied customer purchases at checkout on Microsoft Excel, sorting purchased items into subcategories within each department. The departments in our Excel sheet correspond with the departments in the annual report each ReStore submits to

Habitat for Humanity International (HFHI). We repeated this process at least once for every day of the week that ReStore was open (Saturday, Tuesday, Wednesday, Thursday, and Friday) for approximately four hours at a time.

When the ReStore was not open, we began collecting weight information for the categories of items we had observed being purchased. We utilized physical weighing using a large pallet scale for big items and a kitchen scale for smaller items and recorded an array of different items per category. We then calculated the average weight for each item category (glass cups, bowls, cabinets, chairs, etc.), which could then be combined with purchase information to accurately estimate the average weight of an item purchased from a given department.

We also created an interactive calculator using VBA (Visual Basic for Applications) in Microsoft Excel. The user interface provided a basic interface to calculate estimated diversion from departmental sales numbers, an interface for adding more departments, and an additional field for entering known weights, for ReStores that sell unique materials (e.g., scrap metal) by weight. Along with this, we crafted documentation that outlined how to use our calculator.

Findings and Results:

We determined that calculating average departmental weights from sales data would be far more accurate than calculating them from inventory or donation data. Rather than focusing on what the ReStore receives or holds in its inventory, we focused on analyzing what went out the door in sales and based our average weight sampling on that information. This avoids the assumption that all items the ReStore has in stock will be sold, which is not guaranteed.

Additionally, we determined that calculating tonnage diversion using the number of items sold is preferable to calculating tonnage diversion from revenue. Converting from items to dollars (sale price) and dollars to diversion (estimated tonnage per dollar) introduces errors

related to pricing, including mark-downs on items that are not selling, as well as inaccuracies caused by inflation and variations in pricing between regions, on top of the inherent uncertainty involved in estimating weight from the dollar value.

Habitat for Humanity initially expressed their desire for a CO2 diversion calculator to be created alongside our landfill tonnage diversion calculator. We reviewed the feasibility of such a calculation and concluded that it was not within the scope of our project. Unreasonable assumptions must be made to derive diverted CO2 emissions from sales data, and this was found evident in a report done by another college project team. Due to the significant uncertainties and the scope of the investigation that would be required, this area of investigation was dropped in favor of focusing on our core tonnage diversion methodology and interface.

Recommendations and Conclusions:

The data we have collected is intended to be preliminary, as it is not an accurate representation of national data as it only includes data gathered over a short time frame from a Worcester, MA and Ashland, MA ReStore. More data collection is required to ensure that each unique ReStore throughout the nation has an accurate representation of the inventory they carry and their customer purchasing behavior. We recommend that Habitat for Humanity International (HFHI) reach out to ReStores nationwide and ask them to collect data in the style we presented in our deliverables and report the data to HFHI. This data can then be compiled and used for analysis of national sales data.

We have ensured that our method is scalable, sustainable, and easy to learn and implement. We recommend that data be updated as needed by each ReStore, to ensure data continues to follow trends in sales and the movement of inventory.

Authorship

Each section of the report was divided amongst the team to complete. Once a section was drafted, the team as a whole read it over and made note of any suggestions. Feedback was also received from our advisor, and proper revisions were made.

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Introduction

The Habitat for Humanity organization was founded in 1985 by affordable housing advocates in Georgia. Since its humble beginning on a Georgian farm, Habitat has since helped more than 35 million people improve their housing conditions, over 70,000 new homes built, and repairing at least 100,000 more (Habitat for Humanity, n.d.a). The non-profit organization selects homeowners who are willing and able to work with Habitat and provides them with everything they need to become first-time homeowners. The chosen homeowner works with a network of their family, volunteers, and the Habitat organization to put 300 hours of "sweat equity" into their project home (Habitat for Humanity MetroWest/Greater Worcester, 2020). Through this, the family pays an affordable mortgage and takes relevant classes, including instruction on personal finances and home maintenance and repair.

Figure 1. Individuals served by Habitat for Humanity (1976-2020)

Habitat for Humanity also operates multiple “ReStore” locations, where they accept donations of lightly used furniture, materials, and appliances and sell them back to the community at discounted prices. Their inventory changes daily, offering a continuous fresh selection for shoppers. Resale stores are an excellent resource for many people, especially for new homeowners looking to furnish their residences on a budget while keeping perfectly usable furnishing, appliances, and other household materials out of landfills. Any materials sold through ReStore locations are considered to be “diverted” from local landfills. Often reported in tons as “tonnage diverted,” this metric benefits Habitat for Humanity when seeking donor grants. The ReStore is Habitat for Humanity's primary source of revenue, and these resale stores help fund Habitat’s mission of building affordable homes.

The Greater Worcester/Metro-West branch of Habitat’s ReStore contacted WPI for assistance revising their weight estimation method. Two student groups have previously done work on this method, one from the University of Wisconsin-Madison (Bindl, 2022) and one from WPI (Daly, 2015). However, much of their work was lost or proved unsuitable for implementation.

To avoid similar results and ensure that the weight estimation method developed by our team remains easy to implement, scalable, and sustainable over time, we set the main project goals:

1. To create an accurate and scalable method to estimate landfill tonnage diversion.
2. To ensure this method is unobtrusive and does not require significant changes to ReStore operations.
3. To ensure the method can be applied with minimal training by providing a simple and understandable visual interface with accompanying documentation.

Background

Poverty in MA

Massachusetts has struggled with prolonged poverty, and data from government sources shed light on the problem's scope and severity. The poverty rate in Massachusetts in 2019 was 10.2% (U.S. Census Bureau, 2021), which is somewhat lower than the national average of 10.5%. There is a continued need for aid and resources to combat poverty in the state. An estimated 679,000 people, including children, received assistance through the Supplemental Nutrition Assistance Program (SNAP) in 2020 (Massachusetts Department of Transitional Assistance, 2021).

In addition, homelessness is still a major issue within the state. In 2018, there were around 20,068 people without homes in Massachusetts (Massachusetts Coalition for the Homeless, 2022) Almost a third of them were children and families. Evidence like this highlights the need for all-encompassing approaches to tackling the root causes of poverty and housing insecurity.

In 2020, the poverty rate in Massachusetts was 9.8%, and 12.8% of the United States population is below the poverty level, while the unemployment rate in 2021 was 5.7%. The average annual pay in MA was 2021 was $87,668 (Statista, n.d.) The average rent prices in Massachusetts are high, which is a financial burden for many families compounded by the state's high cost of living. As renting a studio apartment in Worcester is $1,250 a month or $1,661 for a one-bedroom apartment, rent is a significant percentage of the cost of living in the city, and it increases yearly (Woods, 2020). Figure 2 shows that 49% of households in Worcester have an

income below 50,000 dollars, which is considered to be under the poverty line in Massachusetts (US Census Bureau, 2020)

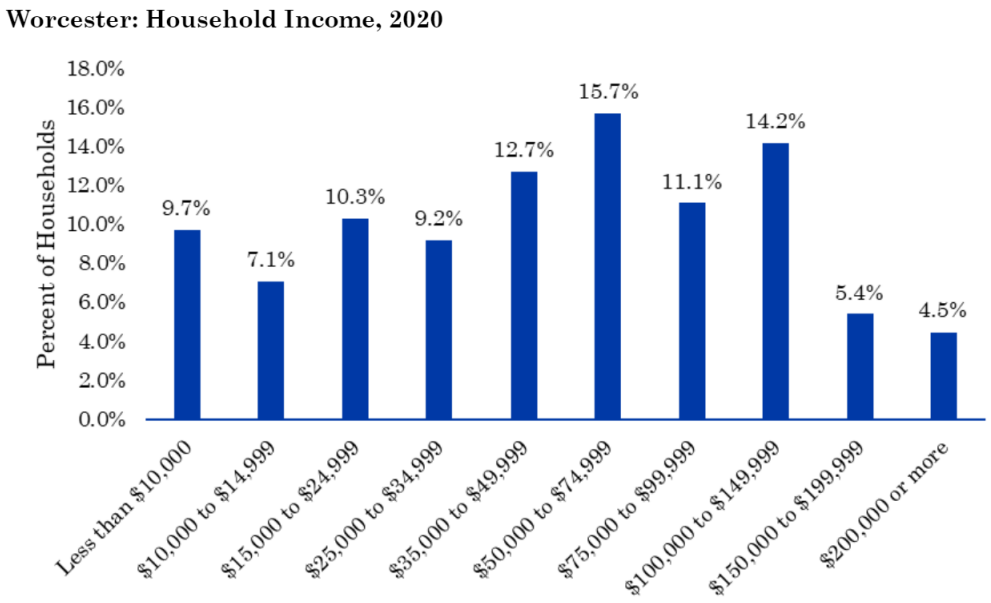

Figure 2. Household Income in Worcester, MA (2020)

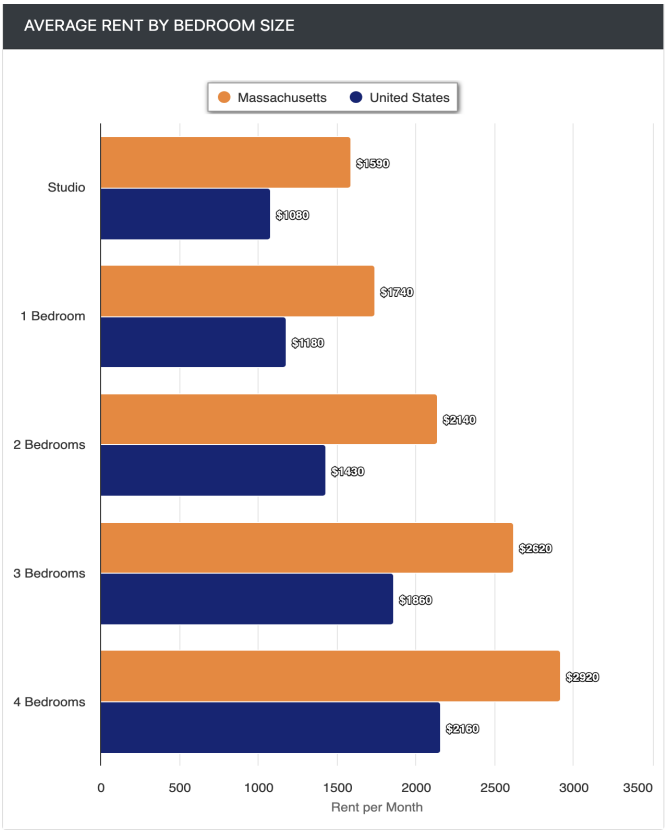

Figure 3. Average rent by bedroom size in MA compared to the US

When added to the $62,000 annual cost of living and the $65,000 median household income in Worcester, Massachusetts, it is easy to see why renting an apartment can be a significant financial commitment for locals (U.S. Census Bureau, 2021). In Massachusetts, the poverty threshold changes depending on the size of the family. For instance, a family of four in Massachusetts would need to earn $26,500 or less annually in 2021 to be considered living in poverty (MassLegalHelp, n.d.) This estimate may differ based on factors such as the varying cost of living in different regions of the state.

Many people in Massachusetts have difficulty making ends meet and achieving financial stability due to factors like high rent rates and the general expense of living. Comprehensive

strategies to provide affordable housing alternatives, boost work prospects, and help low-income people and families are necessary to solve these problems.

The Organization: Habitat for Humanity

For more than four decades, Habitat for Humanity has been working to improve people's living conditions and build stronger communities worldwide. Since its inception in 1976 by Millard and Linda Fuller, the organization has assisted millions of people in constructing and renovating their homes, giving them a place to call their own that is both comfortable and safe.

The mission of Habitat for Humanity is “Seeking to put God’s love into action, Habitat for Humanity brings people together to build homes, communities and hope” (Habitat for Humanity, 2023. b.) The group dedicates itself to ensuring that people in need have access to adequate, reasonably priced places to live, as they view this as a fundamental human right. To construct, rebuild, and repair houses, Habitat for Humanity collaborates with volunteers from all walks of life in more than 70 countries.

Habitat for Humanity's "sweat equity" methodology is one of the most distinctive features of its housing approach. Homeowners in this model put in time and effort with volunteers and Habitat for Humanity employees to complete the construction of their houses. As a result, they learn fundamental construction skills and develop a strong sense of personal investment in their homes. Crucially, Habitat for Humanity also provides affordable solutions to these first-time homeowners, helping them establish a stable financial future for themselves and their families.

Habitat for Humanity's holistic approach to community development also focuses on more than just building houses - together with community members, local businesses, and

government agencies, Habitat for Humanity helps build strong, resilient neighborhoods by improving access to healthcare, education, and jobs (Habitat for Humanity, n.d.c).

Habitat for Humanity relies heavily on its dedicated volunteer base. Their home construction and maintenance programs receive support from thousands of volunteers annually. Volunteers, whether seasoned construction workers or first-time helpers with no background in the field, are essential to Habitat for Humanity's success. In addition to helping out on construction sites, volunteers can also help out at one of Habitat's many ReStores, which sells used furniture, appliances, and building supplies to generate revenue for the organization.

Figure 4. Habitat for Humanity Volunteers helping at a build site

The reach of Habitat for Humanity's work is extensive. Since its foundation, the organization has served 29 million people and granted them the ability to live in secure and inexpensive environments (Habitat for Humanity, 2019) The work of Habitat for Humanity is about more than just constructing houses; it's also about fostering optimism and opening doors to prosperity. Habitat for Humanity's forward-thinking approach to housing and community development makes it possible for people from all walks of life to realize their full potential.

Locally, the MetroWest/Greater Worcester branch serves over 42 towns in the central Massachusetts area. The branch was founded in 1985 and opened its ReStore later in 2010. Since its founding, Habitat MWGW has built 53 homes in its service area.

The Importance of the Habitat ReStore

The Habitat for Humanity ReStore is a major income source for the Habitat organization to fund its mission and is significant for several other reasons. They provide affordable housing materials and supplies for low-income families and individuals. The ReStores offer various new and gently used items such as furniture, appliances, building materials, and home goods at discounted prices. Families then have access to inexpensive materials needed to build, repair, and furnish their homes.

Figure 5. Inside of a Habitat for Humanity ReStore

ReStores are environmentally friendly and support a circular economy. By selling recycled items, they help reduce waste and promote sustainability. This practice is essential, especially in today's world, where climate change is becoming an increasingly urgent issue. The ReStore's also accept donations of used items, which keeps them from being thrown out and landfilled. This then reduces the need for new products to be manufactured.

Further, the ReStores benefit the local community. They help boost home ownership, quality of living, and quality of housing by providing affordable housing materials and furnishings. This assistance can lead to safer and more stable communities. Additionally, the ReStores often offer residents job training and employment opportunities, which helps the local economy.

The ReStores are a major funding source for the Habitat for Humanity organization, which again seeks to eliminate homelessness and improve living conditions for families. By supporting ReStores, the community can help advance its critical mission and make a difference in the lives of families and other communities worldwide.

A circular economy

The Habitat for Humanity ReStore supports a circular economy. Rather than having items thrown out, Habitat takes lightly used donations and resells them. These items are reasonably priced, making them coveted by buyers on a budget.

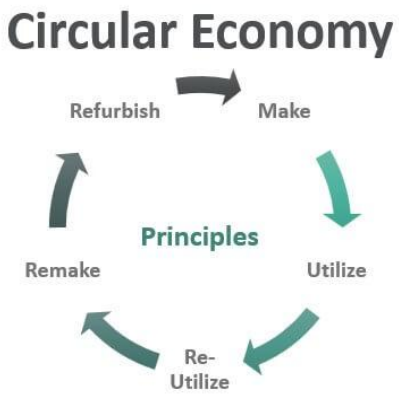

Figure 6. Principles that define a circular economy

A linear economy model is traditionally practiced in our society and is defined as a take-make-use-destroy design (Govindan, 2018) in which humans take resources, make products,

use these products, and then destroy them. While simple to implement, this system places significant pressure on our environment. These, and similar forces, drive global issues such as climate change and loss of biodiversity. Our economic practices are not sustainable, and change is necessary to mitigate further harm.

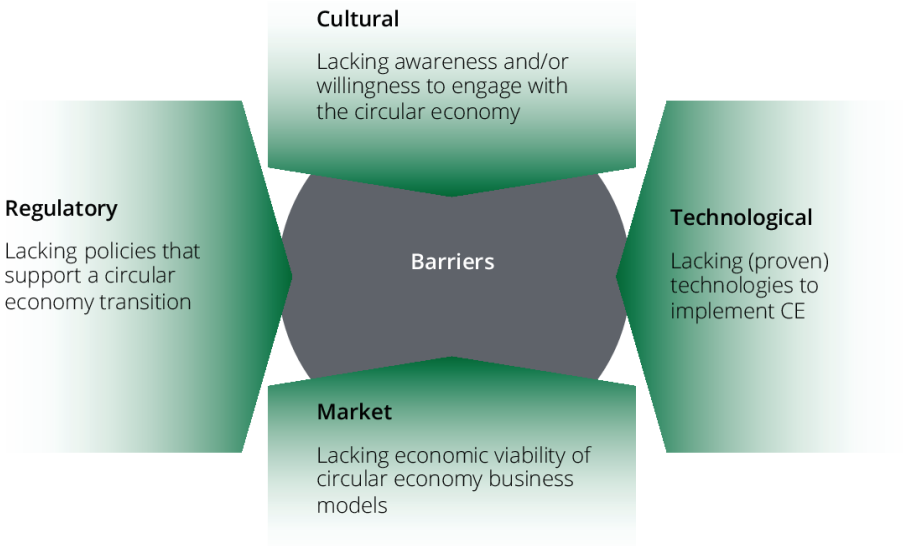

Figure 7. Barriers preventing companies from adopting a circular model

Many leaders in sustainability, such as the Environmental Protection Agency, The United Nations, and the Ellen MacArthur Foundation, have talked of a fresh model, a circular economy. Eliminating waste and pollution, circulating products and materials at their highest value, and regenerating nature are the three principles of a circular economy is defined by (Ellen MacArthur Foundation, n.d). When it replaces a linear economy, a circular economy produces positive benefits to not only the environment, but also to our financial system, and the government officials who tend to oppose the implementation of sustainability measures. Through product modeling, it is reported that supply chain organizations have an estimated $340–$380 billion per year saving opportunity (Govindan, 2018), representing net material cost savings when switching to sustainable practices.

Barriers exist in deploying this economic model. Supply chains are highlighted, as these sectors contribute significantly to the linear economy by producing non-sustainable products. Government enforcement of sustainable chains is not strict, allowing companies to find the easiest and upfront-cheapest practices, often harmful to the environment. Furthermore, the absence of governmental financial support leads to a lack of business interest in adopting such new processes. With proper incentives and tax structure, however, a circular approach could be made to appeal to even penny-pinching businesses.

Landfill tonnage diversion

The term "landfill diversion" describes the process of identifying viable alternatives to landfill disposal for waste products. The goal is to encourage more environmentally friendly waste management techniques and reduce the volume of garbage sent to landfills. Recycling, composting, waste-to-energy conversion, source reduction, donation and reuse, and safe hazardous waste management are all methods that may be used to achieve this goal. This waste diversion also reduces disposal costs and the burden on landfills (EPA, 2022). We can reduce pollution, save resources, prolong the life of landfills, and promote a cleaner, healthier environment if we divert trash from them. Community organizations and charities may also salvage furniture from landfills.

To quantify ReStore's contribution to this process, a metric known as "landfill tonnage diversion" is used by Habitat for Humanity. This metric describes the total weight, in tons, of material diverted from landfill. Alongside landfill diversion's social and environmental benefits, this metric can be used to advertise Habitat for Humanity's operations to potential donors and apply for grants.

The 2015 Habitat for Humanity Project

Habitat for Humanity Greater Worcester contacted WPI, seeking assistance in redeveloping their weight estimation method. Since Habitat for Humanity is a nonprofit organization, they use grants to fund their operations. To receive these grants, organizations like Habitat must report tonnage of material diverted from landfill, and this metric gives foundations, corporations, or government agencies an idea of how much material Habitat has kept out of landfills.

In 2015, Habitat for Humanity collaborated with a project team from WPI to create a new weight estimation protocol, which developed two estimation methods. The first method was a program that used a manually filled database to calculate the average weight of the items in each department of the ReStore. This average value was then multiplied by the total recorded sales from each department to determine the total weight of merchandise sold by each department at the end of every month.

The second method of weight estimation that the 2015 project team used involved creating a conversion factor that they could multiply by the total value of items sold over a month to determine the weight of items sold during that period. To determine this conversion factor, the 2015 team created a proportional relationship between the total price of items sold and the weight of those items, broken down by department such that each department receives its conversion factor. These factors were then compared to ReStore's existing assumption for value per lb of sales, which was $1.3 per lb of material. For many years, Habitat for Humanity has been using the simple but largely unverified metric of 1.3 pounds diverted for every dollar of merchandise sold by ReStores.

While these two methods were shown by the 2015 project to be sufficiently adequate for the ReStore's needs at the time, their data and database structure were unfortunately lost before it could be reimplemented or replicated later. This metric has been easy to use, however, the organization lacks sufficient data to support its assumptions. Our project intention is to improve upon the methods presented by the team, collect and deliver preliminary data, and develop tools to enable Habitat for Humanity to implement, maintain, and refine the resulting data and methodologies.

Methodology

As previously stated, the goals of our project were threefold:

1. To create an accurate and scalable method for landfill tonnage diversion estimation.
2. To ensure this method is unobtrusive and does not require significant changes to ReStore operations.
3. To ensure that the method can be applied with minimal training by providing a simple and understandable visual interface with accompanying documentation.

We implemented an iterative design and data-collection process to achieve these goals, focusing on the development and cohesion of our data-collection process, our landfill tonnage diversion estimation method, and our visual user interface

Beginning with a day of volunteering in the Worcester ReStore, we built a knowledge of ReStore operations and watched customer purchasing behavior and associated inventory flow. From this process, we came to several important conclusions about ReStore's inventory. Firstly, the average weights of items can vary significantly between departments, and per-department sales distributions are not guaranteed to be static year-over-year, let alone between various ReStore locations. As such, diversion estimation must be done on a per-department basis. Additionally, weight spread within each department can vary dramatically, and customer purchases are not guaranteed to be evenly distributed among all items in a given department. This means that per-department weight estimates should account for inventory flow and variation in weight between item types within departments With this knowledge, we developed a simple methodology for collecting customer purchase data and correlating that data with real-world item weights.

Over several weeks, we tallied customer purchases at checkout, sorting purchased items into subcategories within each department. For example, glass cups would be marked as “glass cups” in the household department, a bowl would be tallied as “bowl” in the same department, and a lightbulb would be counted as “lightbulb” in the lighting department. Subcategories were made broad enough to make data analysis and measurements feasible and significantly narrower than existing department classifications. This addition allowed us to observe the distribution of items purchased within each department. We repeated this process at least once for every day of the week that ReStore was open (Saturday, Tuesday, Wednesday, Thursday, and Friday) for approximately four hours at a time.

On days when the ReStore was not open, we began collecting weight information for the categories of items we had observed being purchased. Our goal was to obtain a useful average weight for each item category (glass cups, bowls, cabinets, chairs, etc.), which could then be combined with purchase information to accurately estimate the average weight of an item purchased from a given department.

Item	# of items
Utensil set	8
Photo frame	16
Statue	2
pins (wearable)	5
Big glass bowl	12
Plates	58
Porcelain knick-knack	3
Plastic knick-knack	3

Figure 8. Sample of data collection format

The process of collecting weight information involved weighing samples of each item type and averaging their weights. Emphasis was put on getting more measurements for common

item categories (glass cups and chairs, for example), as these would be weighted most heavily in our final department averages. We excluded items for which we could not gather measurements from our dataset. Items were weighed using two scales, depending on the item's size. Large and heavy items were weighed on an industrial pallet scale, while smaller and lighter items were weighed on a small kitchen scale.

Item	# of items	Avg. Weights	Weights of Sample Items (lbs)					
Utensil set	8	4.717	3.1125	8.2625	2.775			
Photo frame	16	0.8813	1.20625	0.725	1.5125	0.45	0.5125	
Statue	2	2.375	2.375					
pins (wearable)	5	0.0163	0.04375	0.0125	0.00625	0.00625	0.0125	
Big glass bowl	12	4.25	4.25					
Plates	58	1.471	1.040625	1.875	1.0625	1.875	1.5	
Porcelain knick-knack	3	0.591	0.9125	0.73125	0.33125	0.58125	0.34375	0.64375
Plastic knick-knack	3	0.025	0.04375	0.00625				

Figure 9. Sample of data collection format

Next, we designed a user interface in collaboration with ReStore employees, which will be used by ReStore employees to perform tonnage diversion calculations using sales data and departmental weights obtained through our estimation method. We created a simple prototype using VBA (Visual Basic for Applications) in Microsoft Excel, and gathered relevant feedback on its design and feature set. Excel was chosen as the basis for this interface primarily because of its ubiquity- any ReStore employee who wishes to perform this calculation will know what Excel is and have access to a computer capable of running it. Initially, the user interface provided a basic interface to calculate estimated diversion from departmental sales numbers. During the development and feedback process, we added input error checking (e.g., rejecting numeric fields containing numbers, rejecting negative sales numbers), a visual interface for adding more departments, and an additional field for entering “known” weights, for ReStores that sell certain material (e.g., scrap metal) by weight.

After the development of the user interface, Habitat for Humanity requested basic documentation covering the use of the interface for distribution to ReStore employees. We created basic documentation, requested feedback on it, and revised it per said feedback.

Research Findings

Through our research, we came to several general conclusions, which informed the direction of our research and the presentation of our conclusions.

Firstly, we determined that calculating departmental average weights from sales data is superior to calculating them from inventory or donation data. If we assumed that all types of items in inventory are sold at an equal rate, then the assumption that the mean weight of an item in inventory equals the mean weight of a sold item would be correct. The distribution of item weights (both inventory and sales) might look something like this, with smaller items than larger ones:

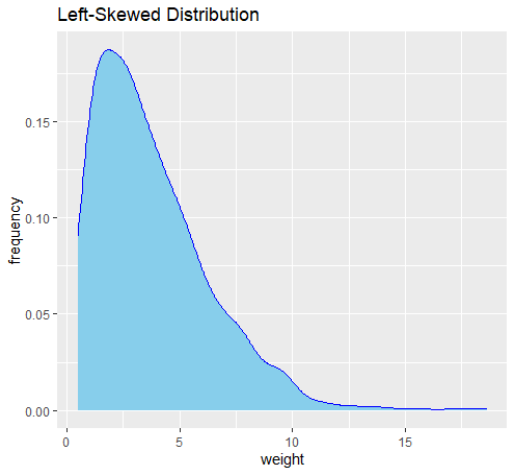

Figure 10 . Distribution of item weights if weight was proportional to frequency of sales

However, if many of the smaller items (for example) sit around for much longer than the heavier items (or get thrown away after not selling), the weight distribution of sold items would be shifted shift like this:

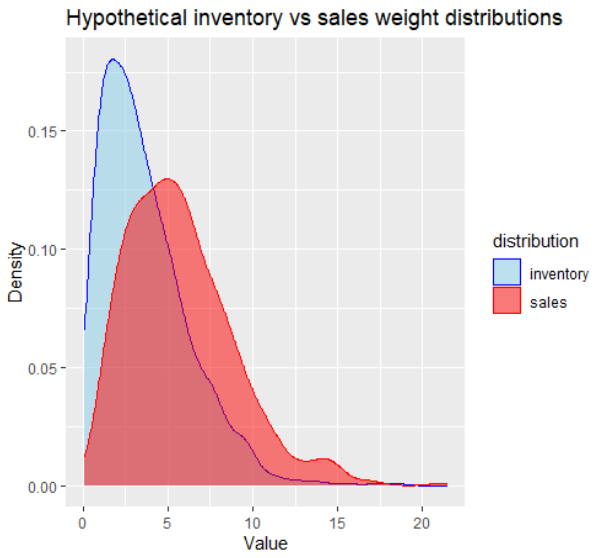

Figure 11 . Hypothetical inventory vs. Sales weight distributions

This could change the mean weight of sold items significantly, and without a reliable method for estimating the distribution of inventory flow, and of inventory that gets thrown away after sitting unsold, there would be no way of correcting for the effects on mean weight.

One real-world example of this from the Worcester ReStore would be the paint department. At the time of writing, the department contains a significant quantity of (very light) plastic paint scrapers and a smaller number of (much heavier) paint cans. A random sample of the paint department inventory would overestimate the impact of paint scrapers on that department's average diversion (because there are so many of them in inventory) when in reality, the inventory flow in that department is primarily driven by the paint cans. As such, diversion calculations performed with such a sample would significantly underestimate the department's tonnage diversion.

Sampling items from incoming donations instead of from inventory can correct for the sales-volume vs. inventory-volume disparity. However, it cannot account for items that never sell and are eventually thrown away. Additionally, donation samples are subject to more noise than

sales samples (for example, one might receive a large donation of the same kind of item, which then sells over several months or years). Because of this, more data is required compared to a similar sample performed on sales data instead. For these reasons, we chose to sample from customer purchases rather than store inventory or donations.

Additionally, we determined that calculating tonnage diversion using the number of items sold is preferable to calculating tonnage diversion from revenue. Every step in the process of estimating tonnage diversion introduces errors and uncertainties. For example, converting from items to dollars (sale price) and dollars to diversion (estimated tonnage per dollar) introduces errors related to pricing, including mark-downs on items that are not selling, as well as inaccuracies caused by inflation and variations in pricing between regions, on top of the inherent uncertainty involved in estimating weight from dollar value. By reducing the number of mathematical steps required (items to diversion, rather than items to dollars to diversion), we can minimize the expected error.

We determined that to aid in adopting our methodology, we needed to provide an intuitive user interface and clear explanations for its use. Although our calculations are designed to be simple, requiring ReStore employees to perform calculations manually will always present a higher barrier for entry and will be more error-prone than an implementation that presents employees with a simple user interface to quickly and reliably perform the necessary calculations.

We determined that our preliminary Worcester ReStore data would not be sufficient for use on a national scale and should be augmented with data collected from national ReStores. Due to small sample sizes and the limited duration of data collection, the data collected at the

Worcester ReStore is most useful as an example for how our data collection processes may be replicated.

Additionally, Habitat for Humanity initially expressed their desire for a CO2 diversion calculator to be created alongside our landfill tonnage diversion calculator. The team reviewed the feasibility of such a calculation and concluded that it was not within the scope of our project. After analyzing a previous attempt to perform this calculation, it was evident that unreasonable assumptions must be made to derive diverted CO2 emissions from sales data. Previous work on this subject (Bindl, 2022) relied effectively entirely on theoretical numbers, both for Habitat for Humanity inventory and for landfill emissions. No analysis was performed of the materials composition of ReStore inventory, nor of how much CO2 is produced during the manufacturing of the products, the output of which is perhaps even more important than the CO2 produced by a product as it decomposes in a landfill. Due to the significant uncertainties and the scope of the investigation that would be required, this area of investigation was dropped in favor of focusing on our core tonnage diversion methodology and interface.

Results

Our results are summarized below and consist of three major components: a data collection process, a landfill tonnage diversion formula, and a visual user interface that allows users to perform tonnage diversion calculations without implementing the formula manually. Additionally, we present preliminary results from applying this methodology using data gathered from a Worcester, MA ReStore.

Landfill Tonnage Diversion Formula

Our data collection process informed the creation of our landfill tonnage diversion calculation. After data collection, we are left with (a) tallies of the kinds of items purchased from each department (ex, five glass cups, six spatulas, three cabinets, two windows, etc.) and (b) the average weights of those item types. By multiplying the average weight of each item type by the number of that type sold (giving the total weight sold of each item type), summing those results within each department (giving the total weight sold in each department), and then dividing department sales weights by total sales from that department recorded in our sample, we can calculate the average weight of an item sold from each department. When these averages are multiplied by the total sales quantities from each department over a given period, the estimated total landfill tonnage diversion for that period is obtained. Due to the limited time and inventory involved in this preliminary implementation, several departments could not be reliably analyzed using this method due either to low sales volume throughout observation (doors, appliances, plumbing) and/or a tendency to be comprised of unique items (lawn & garden, sporting goods, books). As such, several department weights were instead found using a sample of department inventory. While this was deemed acceptable for this preliminary implementation, further

refinement of this data set should consider methods of resolving this issue, either through more extensive data collection or by weighing items from these departments at checkout. Our preliminary data is shown below (departments marked with an asterisk (*) are shown with weights derived purely from inventory rather than using our sales-based method).

department	avg weight (lbs)
household	1.919
windows*	34.143
appliances*	27.583
flooring	135.292
building material*	12
furniture	51.453
sporting goods*	7.977
books*	2.458
cabinets	58.833
electrical & lighting	4.29
hardware & tools	2.644
doors*	44.75
plumbing*	14.083
lawn & garden*	10.0625
paint	8.488

Figure 12. Preliminary average department weights

Visual User Interface

To make performing the tonnage diversion calculation as simple as possible, we developed a user interface (shown below) in Microsoft Excel that will automatically perform the landfill tonnage diversion estimation.

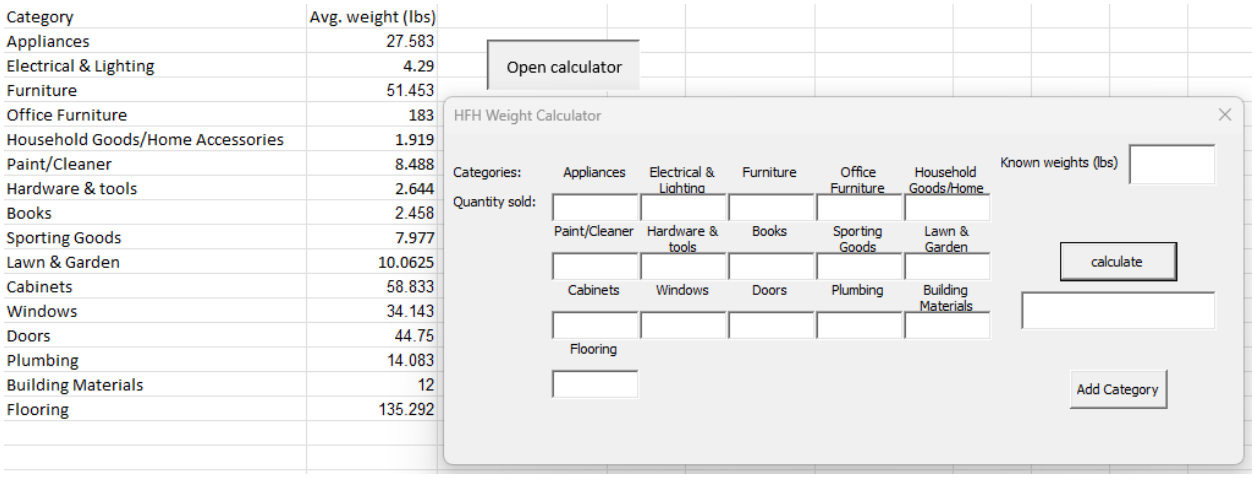

Figure 13. The user interface of the diversion calculator

This user interface requires two things to perform the calculation. First, it requires the user to input the number of items sold from each department over the period of interest into the text field directly below each department name. Second, it requires information about what departments exist in the ReStore the calculation is being performed for and the average weight of an item sold from that department. We provide our data as an example within the calculator, so one must only care about this requirement if they wish to add or remove departments or update the weight information. Instructions on how and why to do this are included in this paper (methodology and results sections) and in supporting documentation for the user interface. When the user interface is run, it creates data entry fields in the center, labeled for each department. Department names are pulled from the first column of the Excel sheet the user interface runs within (figure 13). Once sales numbers are entered into these fields, and the user presses the "calculate" button, the interface performs the tonnage diversion estimation described previously and displays the results in US tons in the text field under the "calculate" button. If the user has known weights (e.g. scrap metal sold by the pound) that they wish to include, that information

may be included in the text entry field labeled “Known weights (lbs)”, and it will be included in the calculation upon pressing “calculate”.

Documentation

Alongside the previously mentioned results, we have included a set of documentation for the calculator interface. This includes a written guide detailing the setup and use of the calculator and a short video walkthrough of the interface and its features. This documentation will be distributed to ReStores alongside the calculator interface and instructions for collecting departmental weight data.

Recommendations and Conclusions

The data presented in this paper is preliminary and is intended as a sample implementation of our methodology. The resulting numbers should not be interpreted as representative national averages as it only includes data gathered over a short time frame from a Worcester, MA and Ashland, MA ReStore.

More data collection is required to obtain useful national information. We recommend that Habitat for Humanity International (HFHI) reach out to ReStores nationwide and ask them to collect data in the style presented in this paper and report that data to HFHI. HFHI can then integrate that data into useful national information.

Along with this report, our team has provided a sample Excel document which is intended to aid in collecting practical per-department sales and weight data. While it is optional to use this document for data collection, it is recommended that a standardized data collection form be provided to participating ReStores to simplify data aggregation. The provided Excel document can be an example of such a standardized form.

In this paper, we have developed and presented tools and methodologies to aid Habitat for Humanity in overhauling its landfill tonnage diversion calculations. These tools and methodologies have been developed to be as sustainable and scalable as possible while remaining simple to teach, implement, and meet Habitat for Humanity's organizational goals. Our team is pleased to have worked with Habitat for Humanity and WPI to complete this project and provided an actionable strategy for modernizing and maintaining Habitat for Humanity's landfill tonnage diversion calculations.

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