RECYCLING MADE EASY: AN ERGONOMIC APPROACH TO HOME RECYCLING AND TRASH CONTAINERS

by

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Abstract

The purpose of this project is create an ergonomically sound recycling/trash container, with the ultimate hope of making the recycling process easier and more intuitive, thereby increasing recycling rates. Currently, while there are many recycling/trash containers available for purchase, there is no product that has a design without glaring ergonomic flaws. An ergonomic design and product prototype was created as a part of this project, and was subsequently tested against a conventional prototype model. The data collected from the experiments conducted suggests that the new ergonomic model makes the waste disposal process and the container transportation process easier, while two-thirds of participants said that they would be more likely to recycle if they were to own the ergonomic model over the generic. Combined with economic analysis showing the need for a family of four to increase recycling rates by a mere 3% over the course of a year for the economy to see a full payback on the $50 purchase price, government assistance is recommended for consumers looking to acquire this product.

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Topic Introduction

This section will introduce the topic focused on by this project, as well as the motivation for undertaking this project and the project goals.

Introduction

The current plan for this senior project is to take an ergonomic approach to the issue of home recycling. When the Environmental Protection Agency last updated recycling statistics in 2007, Americans had generated an alarming 254 million tons over the past year, only 33.4% of which was recycled. More specifically, major home recycling products like paper, metals, plastic, and glass were recycled at rates of 54.5%, 35%, 28.1%, and 28%, respectively. While there has been a significant movement to raise awareness about the benefits of recycling, and there has indeed been a dramatic recycling increase in the last three decades, it is clear there is still considerable room for improvement. The purpose of this senior project is to create a home recycling/trash container which would make recycling easier and more user friendly, with the ultimate goal of increasing the amount of waste recycled in the homes of users.

There is currently a very wide variety of home recycling containers available, including a considerable amount of containers for both recycling and trash. However, the proposed home recycling/trash container displays two features that separate it from the pack. First, the appearance of the product would be designed from a strictly ergonomic perspective, with the goal of making the product's function and purpose as intuitive as possible. Secondly, wheels and a handle have been added to the container, acting as a transport mechanism similar to ones frequently seen on luggage bags. With these features, the potential for human error decreases, and the correct disposal process is more easily achieved. Through ergonomic design, creation of a prototype, and experimentation against a generic product, a model for an affordable home waste container that meets the above criteria and has been created, and has the potential to make a significant positive impact on the recycling industry.

The concept of recycling is one that has been practiced on some level since the beginning of civilization. It started as little more than a common-sense tactic in households across the world. Prior to the industrial age, goods couldn't be produced as cheaply and quickly as they can be today. In many cases, the acquisition of a new product was extremely expensive and/or time consuming, making recycling a near necessity. In fact, it could be argued that mass production itself is the reason large-scale recycling programs have become a necessity.

As a society's ability to make cheap, quick finished goods continues to increase, the concept of "disposable goods" becomes more and more enticing. It often makes monetary sense to purchase an item, dispose of it after consumption/use, and move on to the next one. As we have now discovered however, flooding landfills and accelerating mass production creates a number of serious environmental problems.

It wasn't until the environmental movement of the 1960's and 70's, highlighted by both the creation of the EPA and the first "Earth Day" in 1970 that this problem was brought into the national conscience. Though the recycling movement suffered in its early stages, recycling legislation combined with a slow growing public acceptance has brought the recycling movement to new heights of success.

The ways in which recycling benefits the world's population are nearly countless. Economically, recycling is huge boost in the US. Recycling in the US is a $236 billion a year industry, comprised of over 56,000 recycling/reuse centers nationwide, which combine to employ a staggering 1.1 million employees! (NRC) Additionally, many American companies depend on recycling as a source of raw materials. With that being said, recycling programs are put in place to reap their vast environmental rewards. Most notably, recycling reduces the amount of waste collected in landfills, which benefits us by reducing the harmful chemicals and greenhouse gases those landfills emit into our ozone layer and by saving space in our landfill sites that is becoming more and more precious by the minute. It also curtails habitat destruction and global warming by reducing the need for deforestation, and saves huge amounts of energy as an alternative to producing goods from raw materials. In an attempt to quantify these savings, the National Recycling Coalition claims that the metal cans, plastic bottles, glass bottles, newspaper, and packaging recycled last year saved enough energy to equate to the amount of electricity consumed by 17.8 million Americans in one year! In an age where so much focus is placed on eliminating waste and being frugal with our natural resources, it is figures like these that best highlight the importance of recycling.

Given that our society is in a more environmentally conscious stage than ever before, there has never been a better time to embark on this type of project. The concept of recycling goes hand in hand with our need develop a more sustainable way of life. The motivation for choosing this topic is that this project lends the ability to take the knowledge gained and the skills acquired from the Cal Poly curriculum and apply them with a chance of impacting society for the better.

Product Background

This section will contain a brief background of current products in the market similar to the proposed design, as well as why the proposed design is ergonomically superior to these selected competitors.

Products

There are many numerous recycling and trash containers currently available in the marketplace. Current options vary in size, shape, color, material, and in nearly every other facet imaginable. Thorough research of existing product can help not only to inspire new creative ideas, but can also bring to light glaring shortcomings in existing products which need to be avoided during the design process. In the following product examples, design aspects will be analyzed and critiqued from an ergonomic perspective in hopes of bettering the final design of this current project.

Figure 1: 3-Section Waste Disposal Bin

This 3-Section Indoor and Outdoor Commercial Recycling Bin created by United Receptacle houses both waste and recycling (cans and paper) products in the same unit. Valued at over $2,000, it boasts a sleek steel design and vinyl trim to prevent chipping and damage. The large total volume of 46-gallons minimizes emptying frequency, and rounded edges discourages placement of objects on top of the receptacle.

While this design may be aesthetically appealing, it lacks in ergonomic functionality. Most notably, the absence of pictorial symbols means the communication of separate disposal sections is left solely to text, which presents problems for users unable to read or unfamiliar with the English language. Additionally, the single-color design does nothing to help distinguish one section from another. It is common in many other products as well as government sponsored recycling programs for the recycling container (often blue) to be a different color than the trash container. Employing a multi-color scheme in this product's design would help the user to distinguish the correct deposit area.

Unlike the previous example, this "finger-print proof rectangular recycler" from simplehuman.com is designed for a low-traffic environment such as home or office use. Aside from claiming to be "fingerprint-proof," this brushed steel design employs a foot pedal as a means to open the container without the need to bend over, and two distinct buckets are in place to separate recycling and waste. The small, space-efficient design allows the unit to fit easily in almost any room.

Figure 2: Finger-print proof recycler

Despite the color coding featured in this design used to distinguish the trash and recycling buckets, this product still leaves something to be desired when analyzed ergonomically. First, with no symbol or text located on the outside of the container to suggest the presence of recyclable materials, users unfamiliar with the product have no way of knowing recyclables can be deposited there. Additionally, the color-coding is not visible to the user unless the top of the container is open. Finally, with an available recycling volume of only half that of the waste volume, the product is inconvenient for those users generating as much or more recycling that traditional waste on a regular basis.

The final design to be analyzed is the 16-Gallon Automatic Recycle Touchless Trash Can from Meijer. Ergonomically, we see a vast improvement over the previous two examples. The automatic sensor eliminates the need to open the can, adding to the convenience and eliminating any potential germ problems. The recycling and trash sections are color-coded and labeled with both text and symbols, although only one language is used and the have no traditional association with the product function. Furthermore, the container is equipped with wheels, allowing users to push the container to the next waste disposal site instead of forcing them to lift and carry the waste.

Figure 3: Touchless Trash Can

Despite the vast improvement we have seen, however, there is still significant room for improvement. There is no handle available to assist in the product transportation, and the text is rather small and reaches only those who speak English. Finally, there are options for more intuitive and meaningful symbols than the ones chosen for this product.

Lit Review

This section will detail the 15 most important background resources used in the completion of this project. Each source will be summarized and followed by a brief description of why it is important to the project.

<u>Reference 1</u> – Corona Research, Inc. ***Garbage and Recycling Survey, City of Fort Collins.*** **SERA, Inc. (2005)**

This reference is a summary of a 2005 telephone survey conducted in Fort Collins, CO by Corona Research, Inc. designed to provide a strategic analysis of recycling and waste management options. The 403 survey respondents were asked a wide variety of questions, including those seeking background information to obtain household demographics, preferred recycling methods, and challenges faced in recycling. Some of the key findings in this survey are: the high interest in and support of recycling (98 percent of respondents believe recycling is "good for the city of Fort Collins"), the belief amongst subjects that recycling has yet to reach its full potential, and that the lack of curbside recycling services (37 percent of non-recyclers) and the difficulty/hassle of recycling (35 percent of non-recyclers) are the two biggest reasons for not recycling.

In order to achieve this project's goal of creating a recycling container that makes the recycling process easier and more user-friendly, it is important to understand the recycling tendencies of the general population. Perhaps the most important finding in this survey in regards to the project is that a need has been demonstrated by the non-recycling respondents for the ultimate goal of this project, that being an easier method of recycling.

<u>Reference 2</u> – Christopher D. Wickens, John D. Lee, Yili Liu, Sallie Gordon-Becker. *An Introduction to Human Factors Engineering* (2nd Edition). Prentice Hall, 2003.

This textbook describes the physical and mental capabilities and limitations of the human operator and how these should be used to influence the design of products or systems people use. It outlines general principles of human/machine interaction, and provides examples of both successful and poor ergonomic design. It shows how to apply the theory of human performance in a practical manner, usable in the real world.

Many facets of this book will be extremely helpful in the design phase of this project. In order for this project to be a success, it is critical that capabilities of the operator be at the forefront of the design process, with the ultimate goal being to enhance those capabilities while compensating for operator shortcomings.

<u>Reference 3</u> – "Recycling Facts." *epa.gov.* Environmental Protection Agency, n.d. Web. 9 Dec. 2009.

The Environmental Protection Agency's government run website houses many of our countries official statistics on recycling. Specifically, the website shows the trends in both total waste generated as well as the percentage of that waste that was recycled from 1960 – 2008. Additionally, recycling information is broken down in more detail for 2008, the most recent year of statistics collected. A pie chart breaks down the total waste generated into categories, and is accompanied by a bar graph that shows the percentage of the waste in each category that was recycled.

Recycling statistics are important in the development of this project because it confirms that there is in fact room for and a need for improvement. The 2008 statistics that break the waste down into categories allows the project to focus, if necessary, on certain types of waste in order to maximize the potential positive impact of this project.

<u>Reference 4</u> – Jennifer Snow Wolff, Michael S. Wogalter. "Comprehension of Pictorial Symbols: Effects of Context and Test Method" ***Human Factors*****. 40.2 (1998)**

This article details the nature of pictorial symbols as a means of communication and factors that influence the accuracy of their comprehension. The two factors that were involved in the evaluation of symbols were context (whether or not a probable environment in which a symbol would be seen is depicted) and test method (free-response vs. multiple choice). The study concluded that multiple choice tests with less possible detractors (incorrect answers) artificially inflated comprehension scores by nearly 30%, while the addition of correct context increased symbol comprehension and the use of context when producing symbols can help reduce cost by making the symbol more effective.

This article is relevant to the project topic because as attention toward multiculturalism and effective communication across countries has increased, pictorial symbols have been used more and more frequently to communicate. Effective symbols communicate large amounts of information much quicker than text, and are more effective in communicating with those who are unable to read, or are unfamiliar with the potential language used for communication. The best way to assure that the proposed product is used most effectively by potential customers of all ages, cultures and verbal skill levels is by incorporating well-designed pictorial symbols.

<u>Reference 5</u> – Neil Taft, Chuck Taft. *Recyclingsupply.com*. Web. 9 Dec. 2009.

Recyclingsupply.com is a site that both promotes recycling and all its environmental benefits, but also boasts the one of the widest collections of recycling containers on the web. Available for purchase is everything from office and commercial recycling bins, to home containers, to specially designed school-oriented recycling containers. With over 1200 recycling products to choose from, recyclingsupply.com is a great place to get a feel for the current market and innovative technology surrounding recycling containers.

In the process of designing a new product, it is important to research the current competition, both to avoid any potential copyright/patent infringement, as well as identify where any opportunities for entrance into the market might lie. In creating a successful and marketable product, it is important to differentiate from existing alternatives and emphasize its unique benefits.

<u>Reference 6</u> – Stuart M. McGill. "The Biomechanics of Low Back Injury: Implications on Current Practice in Industry and the Clinic." *Journal of Biomechanics* 30.5 (1997): 465-475

The driving force behind this paper is the frequency of lower back injuries in the workplace, and the need to introduce some concepts of lower back injury in order to reduce the risk of occurrence. Some lower-back injury issues are reviewed and discussed, specifically, the types of loads that cause low back injury and issues which are important considerations when formulating injury avoidance strategies such as spine posture, and cumulative loads on the lower back. Finally, some thoughts on current practice are expressed to stimulate discussion on directions for injury reduction efforts in the future, particularly, the way in which injuries are reported, the use of simple indices of risk such as load magnitude, assessment of the injury and development of injury avoidance strategies.

Of particular importance to this project is the section in this paper where the types of loads which cause low back injuries are discussed. It is vital that the product be designed in such a way that these situations are easily avoidable. Among the possibilities for designing to combat these risks are the addition of wheels and a retractable handle, which would allow for users to roll the container to the disposal area, without requiring carrying the load for long distances.

Reference 7 - Idsart Kingma, P. Paul F. M. Kuijer, Marco J. M. Hoozemans, Jaap H. van Dieën, Allard J. van der Beek and Monique H. W. Frings-Dresen. "Effect of Design of Two-Wheeled Containers on Mechanical Loading" ***International Journal of Industrial Ergonomics*** **31.2 (2003): 73-86**

This study details the effect of the two-wheeled container design that is growing in popularity on the mechanical load felt by operators. It delves into the specifics of Dutch design, including attempting to ascertain which design factors, such as center of mass and handle location, have the biggest effect on joint loading in users during pushing and pulling. Upon varying the COM and handle location of a two-wheeled container to test their effect on handle forces and joint loading, the study found minimal torque on the back, shoulders and elbows in standard two-wheel design. However, a displacement of the center of mass in the direction of the wheel axis reduced the force necessary to tilt the container without creating any adverse effects (i.e. additional torque, loading, etc.). Finally, a slight increase in handle height also reduced required vertical force without negative effects.

The benefits of this study in relation to the project will be realized in the design specifics. As the goal of any ergonomic product is maximize functionality and ease of use, the ability to design in such a way that total load and torque felt by the user is minimized will be another great product benefit. The Dutch designs discussed in this study will serve as a starting point in the design of any potential handle/wheeled portion of the design.

<u>Reference 8</u> - **Robin R. Jenkins, Salvador A. Martinez, Karen Palmer and Michael J. Podolsky. "The determinants of household recycling: a material-specific analysis of recycling program features and unit pricing."** ***Journal of Environmental Economics and Management*****: 45.2 (2003): 294-318**

This paper analyzes the impact of two popular solid waste programs on the percent recycled of several different materials found in the residential solid waste stream. A set of data representing middle and upper-middle income groups in 20 metropolitan statistical areas across the country is examined, containing information on the percent recycled of five different materials: glass bottles, plastic bottles, aluminum, newspaper, and yard waste. The study finds that access to curbside recycling has a significant positive effect on the percentage recycled of all five materials and that the level of this effect varies across different materials. The length of the recycling program's life also has a significant positive effect on two materials. Making recycling mandatory has an insignificant effect on all five materials.

This study can be used to attempt to discern which regions of the country are inclined to recycle in the home, and therefore would be viable candidates for purchasing the product. If the marketing and production of the product can target those areas and cities that employ curbside recycling programs, there should be a noticeable sales boost when compared to the possibility of simply marketing and pursuing all areas equally.

Reference 9 - B. Schibye, K. Søgaard, D. Martinsen and K. Klausen. "Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins." ***Clinical Biomechanics*** **16.7 (2001): 549-559**

The purpose of this paper is to compare the force exerted on the shoulders and lower back during pushing and pulling of a two-wheeled container with lifting and carrying of the same load. Seven experimental participants both pushed and pulled a load the same distance, before carrying a paper bag with an equal amount of waste. The experiment was video recorded and the forces were measured using computer software, calculating compression and shear forces along with torque at both the shoulder joints and the connection of the L4/L5 vertebrae. The torque in the lower back was low during both pushing and pulling.

This study confirms the widely held belief that it is in fact easier on the lower back to push/pull a waste container from point A to point B than it is to carry the waste load along the same path. These findings will play a key role in decision making during the design phase of the project, when adding wheels and a handle to the recycling container will be considered.

<u>Reference 10</u> – G.P. Glasby "Sustainable Development: The Need for a New Paradigm." ***Environment, Development, and Sustainability*** **4.4 (2002): 333-345**

This journal entry outlines the overall challenge the human race faces in terms of our environment and ever dwindling natural resources. The author details our current industrial practices and waste forming habits, and warns us against the damage and destruction we are subjecting our planet to. We are given cautionary tales of historic collapses of advanced civilizations in years past, and reminded that, at our current pace, a worldwide collapse is a distinct possibility. The author argues that the 21^{st} century will be looked upon by future generations as the defining period thus far in mankind's existence, and pleads for a change in the status quo.

This article does a great job of explaining why drastic change in our environmental practices is an absolute *necessity.* While building a sustainable society is a many-faceted and extremely complex task, one of the fundamental building blocks of such a society is an efficient recycling program. This reference validates the overall goal of this project, and definitively explains why it is so important. We desperately need to decrease the rate at which we are consuming the world's resources, and recycling can be a major key in that effort.

<u>Reference 11</u> – Everson, Michael; Freytag, Asmus. "Background Information on Recycling Symbols" ***ISO/IEC Working Group Document N2342*** **(2001)**

This document is the product of research performed by the authors in to the use and history of various recycling symbols. In addition to the original and universal recycling symbol created by Gary Anderson, the winner of a contest in 1970, the paper also details the origin and use of many material specific recycling symbols, as well as symbols that indicate a product is made from recycled material. Overall 20 different symbols are discussed, each with its own specific use and meaning.

Because of the multitude of symbols and meanings involving recycling, it is important to carefully analyze which option is best suited for a given product. For this particular project, it seems as though the universal recycling symbol would work best for a couple reasons. First, it is the oldest, and most recognizable of the symbols. Second, it applies to all types of recycling materials. Given that this product is designed to accommodate all recyclable materials, it is extremely important that the symbol chosen does not have a material specific connotation.

<u>Reference 12</u> – P.L. Gonzalez-Torre. "Influence of distance on the motivation and frequency of household recycling" ***Waste Management*** **25.1 (2005): 15-23**

This study analyzes the influence of walking distance to the recycling bin on the tendency of subjects to recycle. The method of data collection for this study was through survey participation and personal interviews. The study shows that people who throw trash away most often are more likely to recycle. In most cases, the study also shows that, as the distance from the trash bin to the recycling bin decreases, the fraction of participants that separate waste and recycling at home increases.

This study is of obvious importance to this project because it suggests that, in fact, having waste and recycling deposited in the same container (effectively reducing the distance between the recycling container and waste container to zero) would increase the percentage of waste recycled in the home of users. Without this fact, one of the major motivating factors behind this project would be lost. Also, if the proposed product does in fact reach an advanced stage of production and is under consideration of investors, this study and be used as a selling point for the use and benefit of the product.

<u>Reference 13</u> - Leung, Wai-Ching. "Conducting a Survey.", *British Medical Journal, Student Edition*, (2001)

This journal entry outlines the proper format for creating a questionnaire. It touches on many key areas and describes how to deal with challenges that survey conductors face. Among the topics covered are: deciding what to ask, how to word questions to get the most possible information, appropriate questionnaire length, and how to administer the questions. The paper declares that a well-written questionnaire should use simple language, ask precise questions, minimize bias and arrange questions so that the level of difficulty and depth of the questions increase as the survey progresses.

Appropriate survey conducting will likely be an integral part of the testing portion of this project. A well-written questionnaire can obtain a wealth of information from participants and give the experimenter a clear idea of the strengths and weaknesses of his product from a user’s perspective.

<u>Reference 14</u> – K.S. Lee. "Effect of handle height on lower-back loading in cart pushing and pulling" *Applied Ergonomics* 22.2 (1991): 117-123

This paper presents results of a study conducted to estimate lower back loadings in cart pushing and pulling. In this study, six subjects of varying weights were asked to push and pull the same cart at different handle heights and two different moving speeds. The study showed that, in general, pushing produced less of a load on the lower back than pulling. However, at the largest of the three heights (1520 mm, 1090mm, 660mm), pulling resulted in less force on the back than pushing did.

This significance of this study to the product design hinges on the incorporation of wheels and an adjustable handle to aid in the portability of the container. With the addition of these features, subjects could push or pull the product to the dumpster area, in the event the load present in the container made carrying the it strenuous or otherwise difficult to carry. Therefore, it is important to consider the range of heights the handle has the ability to achieve, as it should be made possible for the user to adjust the handle to such a height that allows the product to be moved with the least amount of strain possible.

<u>Reference 15</u> – John Ikerd. "Recycling for Sustainability." Professor Emeritus, University of Missouri. Speech.

John Ikerd's "Recycling for Sustainability" does a wonderful job of emphasizing the importance of recycling in today's world. While the widespread trend toward sustainability and going green has been well documented, it is easy to forget just how impactful something simple like recycling can be if everyone joins in the movement. The simple truth is that recycling makes our lives better. It conserves natural resources, along with saving money and stimulating the economy. It has moral and ethical benefits as well, in that we know that when we are recycling we are doing something to better the world for future generations. “We recycle for sustainability not because it contributes to our economic wealth, but because it contributes to our happiness and well-being.”

It is important that John Ikerd’s philosophy is incorporated into this product design. The overall goal of this project is to contribute to a movement that has the potential to make a dramatic positive impact in the lives of not only the current human race, but also those of future generations as well.

Design

This section will outline the design chosen to satisfy the project's previously stated objective. Included will be the specific steps taken to arrive at the solution, as well as all analysis and reason contributing to the final design.

Overview

In designing the ergonomic recycling/trash container for this project, the goal of the design process was similar to that of the design of any ergonomic product. The main objective was to reach a design solution that makes product easy and intuitive to use. This goal was achieved by employing a user-centered design method and fitting the product to its prospective users. To do this, both the appearance and the usability of the product had to be tailored to fit the human body and mind. The appearance must draw the eye and communicate the correct message to the consumer, and the functionality of the product must minimize the effort necessary to satisfactorily complete the waste disposal process it is designed to aid.

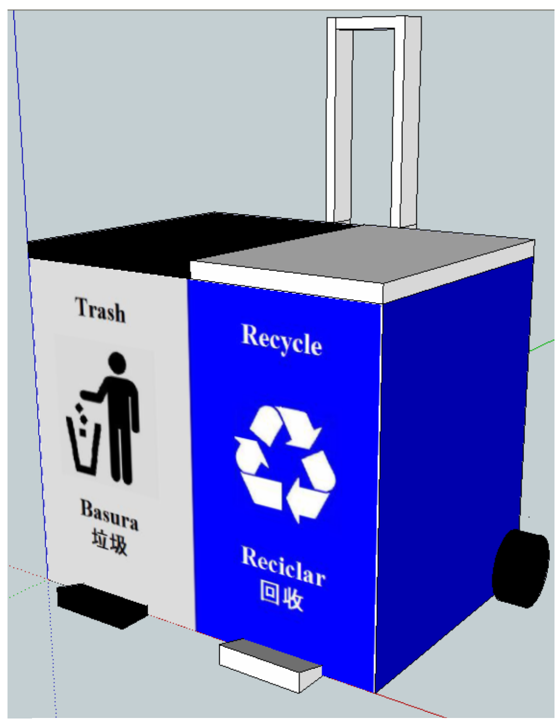

Figure 4: 3D model of ergonomic design

Appearance

The appearance of this product can be simplified into two main aspects: color and labeling. The color of a product is the most easily and universally recognizable aspect of the product, while the labeling conveys a more specific and purposeful message.

The color of the product conveys information about both the purpose of the product and some of its specific features. First, the two-sided background color scheme is immediately noticeable and distinguishes the two separate compartments in the container from one another, right away letting the consumer know that the product is not just one large bin. Secondly, each color is associated with a specific function. In recycling programs across the United States, the majority of recycling bins are blue. It is this reason that blue was chosen for the recycling portion of the product. With a shape similar to that of many waste disposal products on the market, adding a blue background to this product immediately brings the thought of recycling to the forefront of the user's mind. Similar logic can be applied to the choice of gray for the trash side of the product.

The labeling present in the final design might be the most important factor distinguishing this product from those that are similar and currently on the market. The clear and precise information displayed – in multiple forms – on each side of the product makes clear the purpose and function of this product. First, text labeling is included in three separate languages. The languages chosen, English, Spanish, and Chinese, are the three most commonly spoken languages in the United States. [16] The text, which says simply "Recycling" on the blue side in all three languages, was chosen to convey the purpose of the product without cluttering the surface with an overabundance of words.

Additionally, the text is displayed with the first letter only capitalized, as seen in prose, because a message written in all caps is generally harder for people to read. [2]

Symbolic labeling is included as a supplement to the text labeling. It is in place to assist those who do not understand the meaning of the text display. This could occur for numerous reasons: illiteracy, inadequate knowledge of the selected languages, poor eyesight, etc. The symbol included on the recycling section of the product is the universal recycling symbol, comprised of three chasing arrows that form an unending triangular loop. The symbol has been a part of the recycling world for nearly 40 years and is meant to indicate that recycling of all types of recycling materials are housed in the container. The labeling on the recycling section, text included, is white, and was designed so in an effort to both make sure the text has enough contrast to properly stand out and again to conform to common recycling design, in an effort to invoke the memory of previously encountered recycling containers.

The symbol on the trash side of the container is a bit more unfamiliar. The detailed symbol is meant to depict a person dropping trash into a container. On the trash side, the symbol and text color are black, again in an attempt to create sufficient contrast to be clearly readable on the product, but also as a means of further distinguishing the two sides of the product from one another. The symbol is meant to show the purpose of the compartment, trash disposal, in a purely visual manner. The

Figure 5: Trash disposal symbol

text portion of that side, like the other side, includes just one word, Trash, in the three aforementioned languages.

Usability

There are two main tasks performed in connection with this product. First, waste is deposited into the container. Then, once its capacity is reached, it must be taken out and dumped into a larger refuse container that is eventually taken to its final waste disposal destination. With this in mind, two features have been added to the product in the hopes of making each of those two tasks easier. A step-open feature is in place to avoid the action of bending over to lift open the lid of the can. Avoiding this action benefits the user in two ways. It avoids unnecessary strain placed on the back or other areas of the body caused by bending over, and also eliminates the need for the risk of the user's hand to coming into contact with any garbage/germs that might potentially be present on or near the surface of the container.

A more innovative addition is the handle and wheels set. The concept is similar to that applied to travel luggage; the product can be wheeled around instead of needing to be carried, lowering the pressure and torque felt on the subject's shoulders and lower back. [9]

Specifics

The product dimensions are 24" wide, 21" tall, and 17" deep. The dimensions were chosen in an effort to create a volume which would allow for storage of an ample amount of waste, not needing to be taken out constantly, while assuring the product isn't too big to fit comfortably in a living room/kitchen or office area.

The desired volume was calculated after determining the desire for a trash can that would need to be taken out about once every two days on average. Given that the average American produces 4.5 lbs of trash per day, an average family of four would produce 18 lbs of trash each day. At an average trash density of 175 lbs per cubic yard, a family of four would produce just over 16 gallons of trash per day. Therefore, a product volume of 32 gallons should be right at the target of holding two days worth of trash. [3]

The material that the product will be constructed from is High Density Polyethylene, or HDPE. HDPE was chosen for a number of reasons. First, HDPE is, in itself, recyclable. Using recyclable material promotes the purpose of the creation of this product. Secondly, it is fairly cheap, at roughly $0.60 per pound. [17] And finally, the material has all of the properties necessary to work as an effective waste container. Its tensile strength of 4550 psi is much more than required for a standard commercial waste container, and it resists damage when coming into contact with the vast majority of the chemicals one might expect a waste container to encounter. HDPE is resistant to alcohols, acids and bases, and mineral and vegetable oils, operates at extreme temperatures, and should last for decades if properly maintained.

Other minor design specifics:

- <u>Wheels:</u> 3” rubber wheels, 1” thickness bought directly from manufacturer. Weight capacity of 100 lbs. 5/16” axle, hub width 9/8”.
- <u>Handle:</u> Made of same HDPE material. 12” tall, 6” wide, 2” deep. Thickness of 1”. Attached at fixed point on back of container, allows 180 degree range of motion. Adds no extra height when not in use.
- <u>Hinges:</u> Two 1” x 1” hinges will be used to attach the lids to the container.

Experimentation

This section will explain in detail the experimental methods used in testing the product prototype. Each exercise conducted will be explained, with the results of these experiments to be divulged in a later section. The exact instructions given for each experiment can be found in Appendix A.

Overview

The purpose of experimentation on this product prototype is to distinguish what benefits – if any – it has over a generic, non-ergonomic trash can. Therefore, for the purpose of information and consistency, two prototype trash cans were created. One was the ergonomic model designed as a part of this experiment; the other was a generic model, identical to the ergonomic model in size and shape, but without the labeling, color-coding, and features that helped increase usability, i.e. the handle/wheels and step-opener. Three separate exercises were developed as part of the experimentation, with the purpose of comparing the two containers through use of the product, observation, and function.

Exercise 1

In the first exercise, each participant was given one minute to observe each container. After the allotted time, they were asked three questions about each model. The first was an open-ended, short-answer, qualitative question: “Based on your observations, what can you determine about the function and/or purpose of this product?” This question was followed by two questions with response options of Yes, No, and Not Sure. The questions were “Based on your observations, is this a container in which trash should be disposed?” and “Based on your observations, is this a container in which recycling should be disposed?" This exercise and the accompanying questions were meant to identify what information was conveyed by each product before use by the consumer.

Exercise 2

In the second exercise, participants were asked to dispose of a standardized collection of 10 waste items, 5 trash and 5 recyclable, into each container. The set-up of the waste items and the waste container, as well as the waste items themselves, stayed constant in the testing of each model. After completing the exercise, participants were asked just one question about the process. They were asked to rate the ease of the task, on a scale of 1-10, with 10 being extremely easy and 1 being extremely difficult. Upon answering the question, the percentage of items correctly disposed was then tallied and recorded by the experimenter. Exercise 2 addresses the question of whether or not the ergonomic design has an impact on the ease and correctness of the waste disposal process.

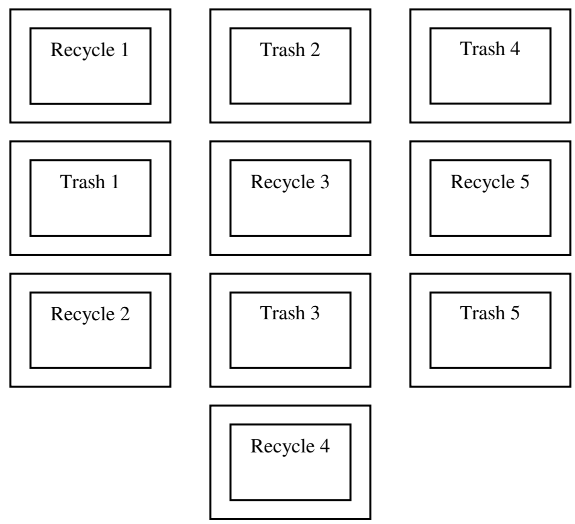

Figure 6: Arrangement of waste items during exercise 2

Exercise 3

In the third and final exercise, participants were asked to move each container with the 10 items inside from a specified location inside the house to a specified location near the street outside of the house, in an attempt to simulate the process of "taking out the trash." After the process was completed, the participants were asked two questions about exercise 3. They were asked to rate the ease of the task on a scale of 1-10, with 10 being extremely easy and 1 being extremely difficult, followed by a question requesting they rate the amount of strain they felt during the process on a scale of 1-10, with 10 being a very high amount of strain and 1 being a very low amount of strain. These questions help in part to gauge the effect the handle and wheels had on the container transportation process.

Summary

After completing all three exercises, each participant was then asked two summary questions. First, they were asked if they felt the waste disposal process as a whole was easier with one product model than the other. This question directly ties to the recycling survey conducted in Fort Collins, Colorado (Reference 1) which states that 52% of non-recyclers say that one of the reasons they don't recycle is because the process is either too difficult or not convenient enough. The second question, which dives straight into the purpose of the project, asks participants if they feel they would be more likely to recycle with either product model. These questions evaluate the opinions of participants on the overall project goals.

Results

In this section we will go over the results of our experimentation and present the resulting data. Additionally, we will address the implications of that data and analyze what it means to the project. Detailed graphs of the data as well as a copy of each survey can be seen in Appendix B.

Exercise 1

The results of the first exercise, observation of the prototypes, generated results close to what was expected. With 10 of 12 participants answering “Yes” to the question of “Based on your observations, is this a container in which trash should be disposed?” in regards to the generic model, and 12 of 12 answering “Yes” in regards to the ergonomic model, it is obvious that the general shape and structure each model held in common made it easy to conclude that both products were designed to house trash. The second question, however, showed much more of a contrast. When posed with the question “Based on your observations, is this a container in which recycling should be disposed?” merely 3 of 12 participants answered “Yes” to the generic model, while all 12 again answered yes to the proposed model. Here is where we see the impact of color coding and labeling. Even though both models had two separate compartments that were the same size, most participants were unable to identify the correct function of the product without assistance from some form of visual ergonomic design.

Exercise 2

In the second exercise, waste disposal, there is a noticeable difference in both forms of measurement. Participants were asked to rate the ease of waste disposal on a scale of 1-10, and an average of 5.4 was found for participants using the generic model, while an average of 9.4 was found using the ergonomic model. The percentage of waste correctly disposed was also calculated, finding averages of 46% correctly disposed using the generic model and 91% using the proposed model.

As forecasted by the results from exercise 1, there was a significant amount of confusion among the participants when trying to correctly dispose of the waste in the generic model. The lack of labeling or any suggestion/direction from the product design makes it difficult for users to determine which side of the container is supposed to house which type of waste. The ergonomic model was a different story, as over 90% of waste was correctly disposed into that model.

Exercise 3

Exercise 3 was design to simulate the process of taking out the trash. Participants were asked to rate the ease of the overall process as well as the amount of strain they felt during the process. In this exercise, the main difference between the two models was the presence of a handle and wheels on the ergonomic model designed to aid the transportation process. In the ease of the process, females noted a significant difference between the models with average ratings of 5 and 9 for the generic and ergonomic models, respectively. However, the males showed less distinction between the two. The average ratings for males were 7 and 8.5 for the generic and ergonomic models. This can most likely be attributed to the general difference in upper body strength between males and females. The upper body strength males possess seemed to lessen their need/desire for an easier transportation mechanism – the handle/wheels – and therefore minimized the contrast between the two scores. When asked the amount of strain felt, males and females this time gave similarly contrasting ratings, with both genders rating the generic model as causing more strain. However, the averages were higher in the female responses, at 2.17 vs. 3.17 for the ergonomic model and 4.66 vs. 6.5 for the generic.

Summary Q's

After all three exercises were completed, each participant was asked to answer to summarizing questions, in an effort to directly address the purpose of taking on this project. The first question, asking if participants felt the overall waste disposal method was easier with either model, was met with a resounding "Yes" as 11/12 participants felt the ergonomic container made the overall waste disposal process easier. The second question, which asked participants if they felt they would be more likely to recycle with one model over the other, found 8/12 participants believe they would be more likely to recycle if they used the ergonomic model over the generic.

Significance Testing

Before performing significance tests on the experimental data, we must first clarify our objective. The goal of this experiment was to find what difference, if any, the ergonomic container design had on the overall waste disposal process when compared to a generic container model. The proposed ergonomic waste container is designed for a home/office setting, in which both genders would use the product an equal amount. Any interaction effect present between gender and model is trivial and has no practical application – it is not practical to expect consumers to purchase multiple containers specifically tailored to each sex. Therefore, the focus of our data analysis will be on the effect had by the different model designs, not on the role that gender plays.

In order to focus solely on the effect of design, male and female data must be analyzed separately. The Anderson-Darling test performed on the data shows that the data is non-normal. Because of this, it would be inappropriate to perform standard parametric data analysis. For this data, the most suitable test is the Mann-Whitney test, which is the non-parametric alternative to the 2-sample t-test. For each test performed, the beginning assumption is that there is no significant difference between the two designs. After the test is run, a statistic is presented that specifies the percentage chance that rejecting that assumption would be wrong, given our experimental data.

The test was performed on the data from the third, fourth, and fifth questions on the survey (shown in Appendix B) given to the experimental participants. In summary, the tests concluded that, at a significance level of .01 or below, the ergonomic model made waste disposal easier (Question 3), container transportation easier (Question 4), and caused less strain during transportation (Question 5). More detailed findings of these tests can be found in Appendix C.

Economic Analysis

In this section, the economics of the project will be discussed in detail. The cost of the product will be derived and the impact of any potential increase in recycling will be measured. The overall economic impact of the product will be outlined.

Cost

The overall cost of this plastic injection-molded product can be broken down into three main categories: part cost, labor cost, and overhead cost. The material cost can be obtained from checking current prices on HDPE and adding it to the cost of the wheels, as well as minor cost aspects such as screws, hinges, etc. The labor and process cost will be estimated with the help of a plastic injection molding cost estimator developed by Dr. David Kazmer of the Mechanical and Industrial Engineering department at the University of Massachusetts, Amherst. This cost estimator will help derive mold and part costs through a thorough step-by-step analysis of historical data. Finally, the overhead cost will be estimated to give us a total estimated cost of the product. In the paper co-authored by Kazmer, "Early Cost Estimation for Injection Molded Components," total product cost is summarized by this equation:

$$\text{Product Cost} = \text{Part Cost} + \text{Assembly Labor Cost} + \text{Overhead per Product}$$

Part Cost – (Assuming Production of 50,000 parts)

Using this method of cost analysis, the part cost can be further broken down into 3 components: the material cost, the processing cost, and the tooling cost. Processing cost in this discussion encompasses the cost of using the molding machine divided by the processing yield. Tooling is simply the cost of the tool amortized over the estimated production quantity for the life of the tool, while the material cost is self explanatory. According to Dr. Kazmer, material cost is calculated using the following equation (where f = material scrapped during processing, estimated at 10%):

$$\text{Material Cost} = \frac{\text{Product Volume x Material Density x Price per pound}}{(1\text{- f})}$$

$$\text{Material Cost} = \frac{\text{(24'', 21'', 17'' dimensions w/ .2'' wall thickness)(0.94 g/cm3)(\$.61/lb)}}{(1 - 0.1)}$$

Material Cost = $9.69

Processing cost is equal to machine cost/hour, which includes labor and energy consumed by the process, multiplied by the number of good parts produced per hour. Dr. Kazmer's cost estimator suggests that a part of these dimensions with average complexity would give us a machine cost per hour of about $97.59 and would produce roughly 76 products per hour, giving us a process cost of:

Process Cost = $97.59/76 = $1.28

Finally, the tooling cost per part is calculated by dividing the cost of the tool by the number of parts produced, 50,000. Dr. Kazmer's estimate of $156,642 for a sufficient tool gives us a tooling cost of:

Tooling Cost = $156,642/50,000 = $3.13

With the part cost of the body calculated, we now must find the part cost for the two container lids and the handle, which will also be created using the same injection molding process. With the above assumptions and calculation processes shown above still applicable, the part cost for each lid = $2.55, handle = $1.64, giving a final *Product Part Cost* of $2.55(2) + $1.64 + $3.86 (2 wheels) + $1.46 (hinges) + $14.10 = **$26.16**

Assembly Labor Cost

The Labor Cost for this part will be estimated using the amount of time it took to assemble each product during the creation of the prototypes. Assembly of each product took roughly 15 minutes, and at $20/hr gives us an *assembly labor cost* of **$5** per product.

Overhead Cost

Using the rule of thumb of $1/sq ft per month, a 1000 sq ft production and storage facility should cost $1000 per month. If 50,000 containers are created in a year's time, we can estimate *overhead costs* as roughly **$0.24** per part.

Total Product Cost = $31.40

Economic Impact of Recycling

Recycling provides our economy with a significant economic benefit. According to the California Integrated Waste Management Board, each ton of waste that is recycled instead of thrown into a landfill generates $275 in goods and services, $135 in sales, and $101 in salaries in wages, for a total of a $511 benefit received by our economy. While a ton of waste might seem like a significant amount, consider that one average family of four produces over three tons of waste *each year*. If the proposed recycling containers were sold at $50 each, it would take less that 1/10 of one ton (50/511 = .098) to generate a return on that investment. If a target is established for each owner of the proposed model to generate a return in one year, a family of four would need to increase their amount of waste recycled by merely 3% in the given year:

(4.5lb trash/day)(4 people)(365 days) = 6,570 lbs of trash per year

6,570/2000 = 3.285 tons per year

0.1 tons/3.285 tons per year = .030 = **3% change**

Conclusions and Recommendations

In this section, the report will be briefly summarized and conclusions from our experimental process will be drawn, as well as recommendations given for what to do next.

Summary

The main objective of creating a waste container design which makes the recycling process easier and more intuitive was achieved. A design prototype was created and tested. Through those tests, statistically significant conclusions were drawn that suggest that the ergonomic waste container model created in this project makes waste disposal and waste container transport easier when compared to a generic model. Additionally, 66% of experimental participants said that they would be more likely to recycle if they owned the proposed model instead of the generic model.

Recommendations

Given that data received and economic analysis performed, it should be recommended that the government assist the public in the purchase of these trash containers. It would take a family of four a mere 3% increase in recycling rates over a given year for the government to see a full return on the proposed $50 price of each container. Given our findings through experimentation about the advantages of the proposed model, it seems very reasonable to expect such an increase.

Future Experimenters

To improve this project, the experimental portion can be taken into greater detail. More design alternatives can be presented, and alternative exercises conducted to expand upon this project's results. Much more work is left to be done in the field of recycling.

Appendix A

Experimentation Instructions

- Exercise 1: In this exercise, you will have one minute from when I start the timer to observe the product and gain all the information you can about it. You are free to look at and touch the product in any way you see fit, so long as it is not damaged in the process. Afterwards, you will be asked a series of questions about the product.
- Exercise 2: In this exercise, you will have five minutes to correctly dispose of all the waste items sitting on the table to your left into the waste container in front of you to the best of your knowledge. After the time is up or all items have been disposed, your performance will be scored and you will be asked questions about the process.
- Exercise 3: In this exercise, you will have two minutes to take the container in front of you to the spot marked on the curb outside while following the designated path. Afterwards, you will again be asked a series of questions about the process.

Appendix B

Graphs of Experimental Data

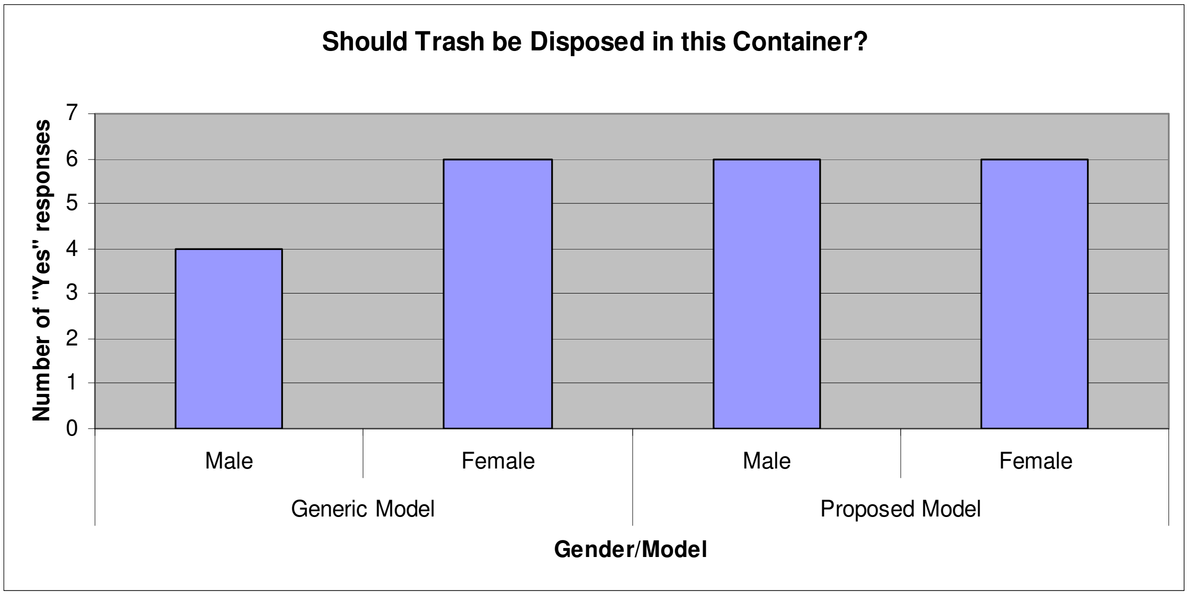

Figure 7: Experimental Data, Question 1

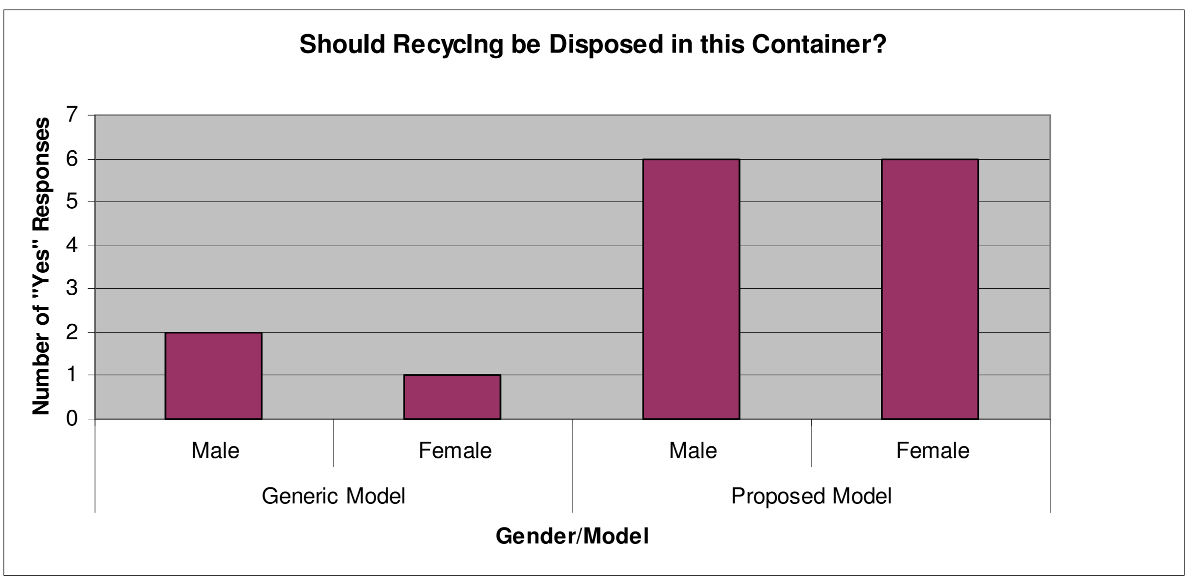

Figure 8: Experimental Data, Question 2

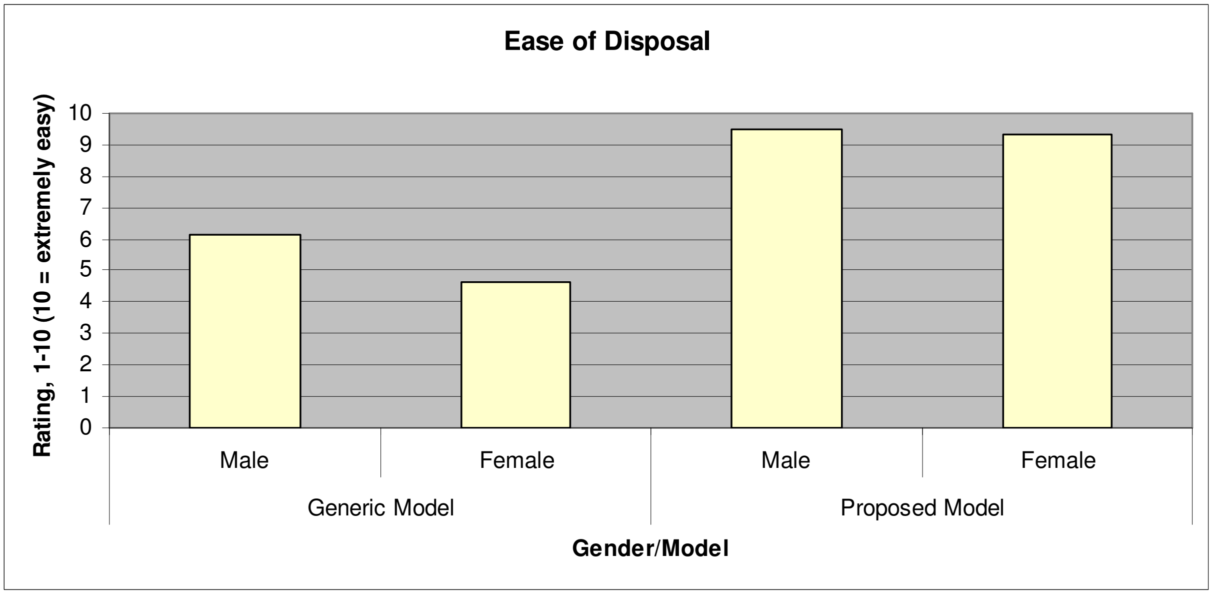

Figure 9: Experimental Data, Question 3

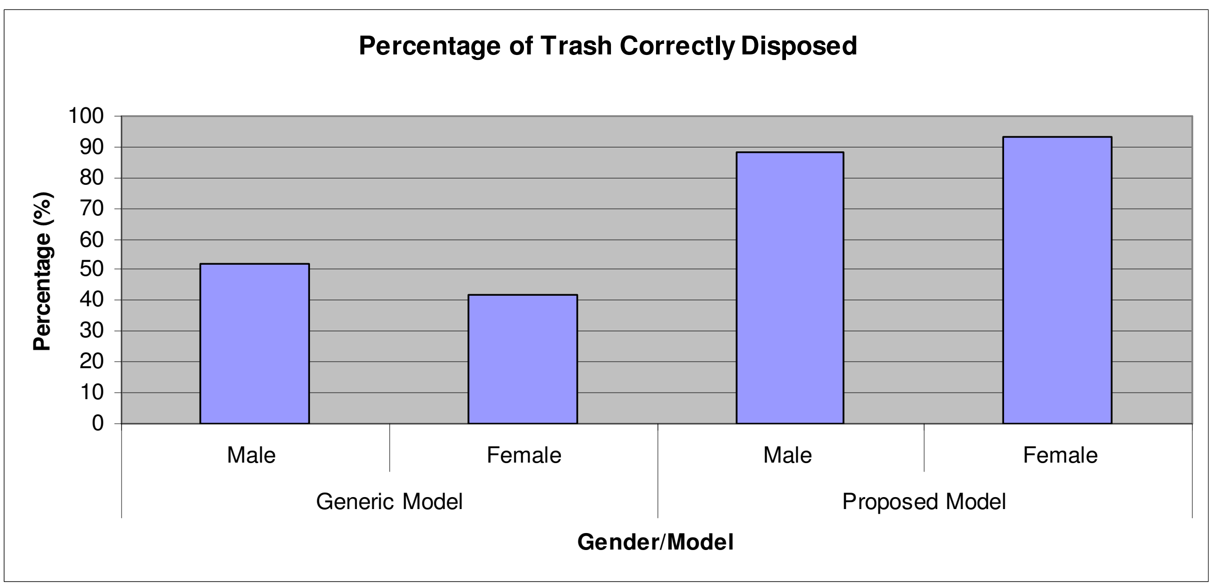

Figure 10: Experimental Data, Question 4

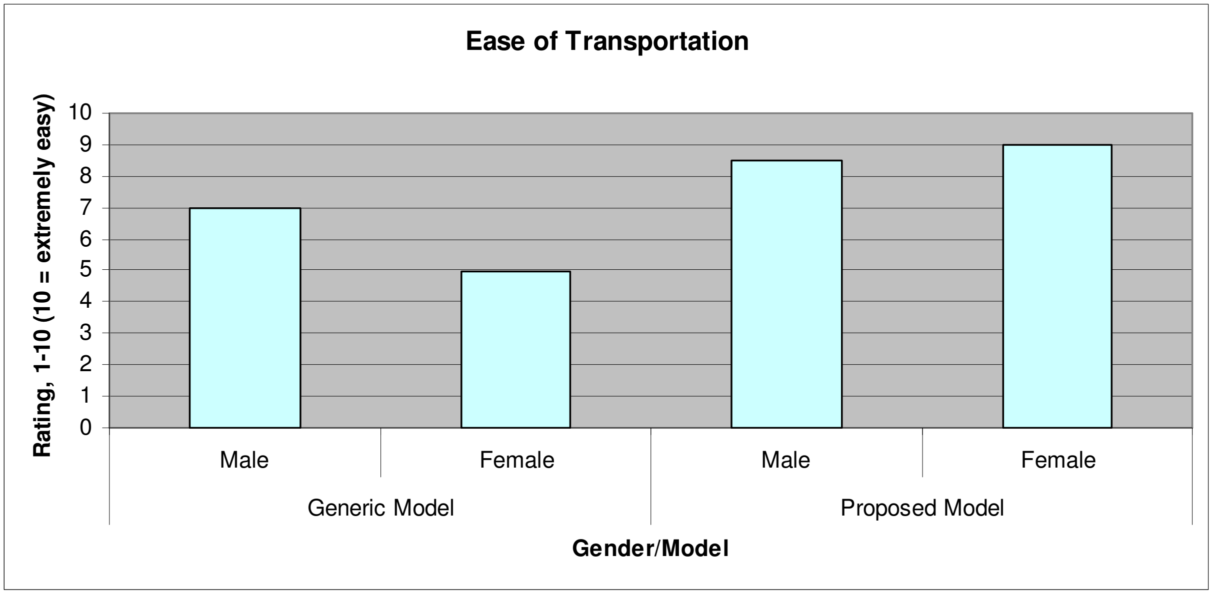

Figure 11: Experimental Data, Question 5

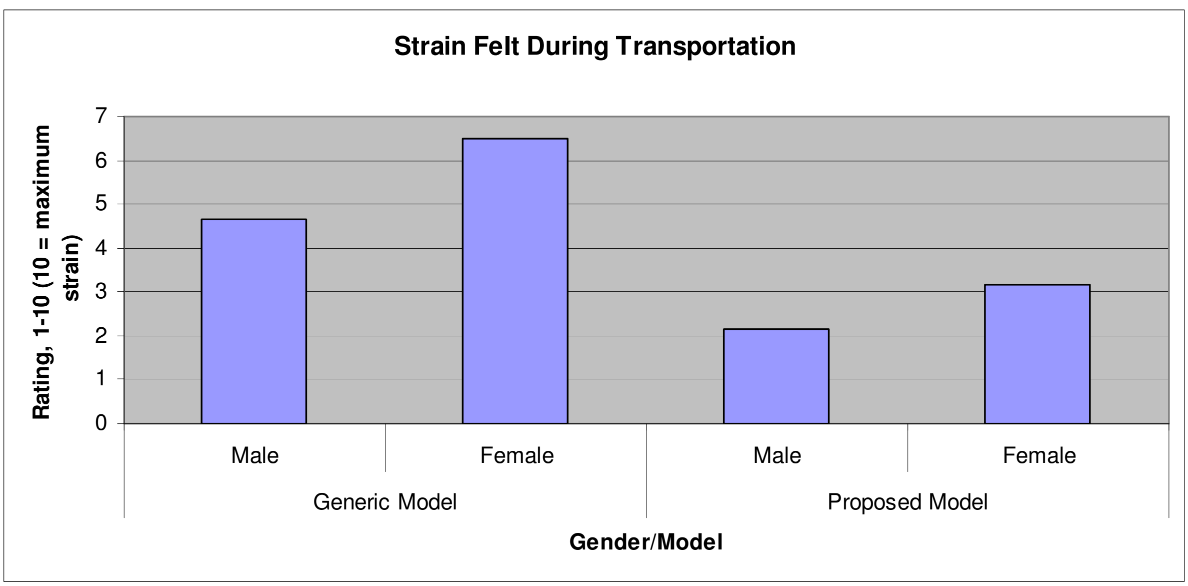

Figure 12: Experimental Data, Question 6

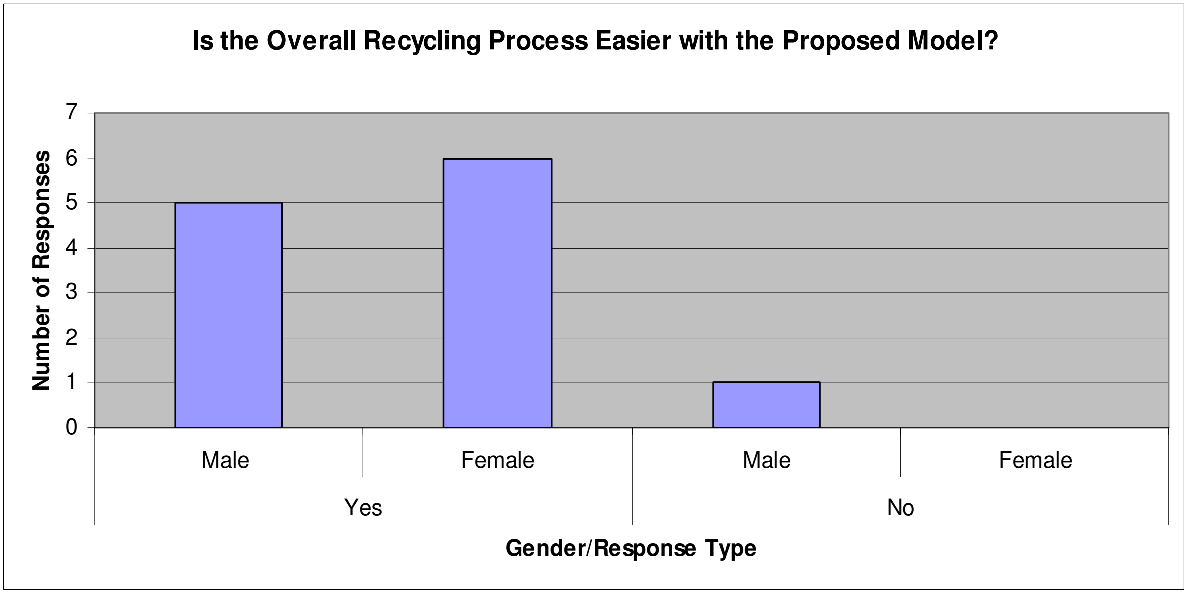

Figure 13: Experimental Data, Question 7

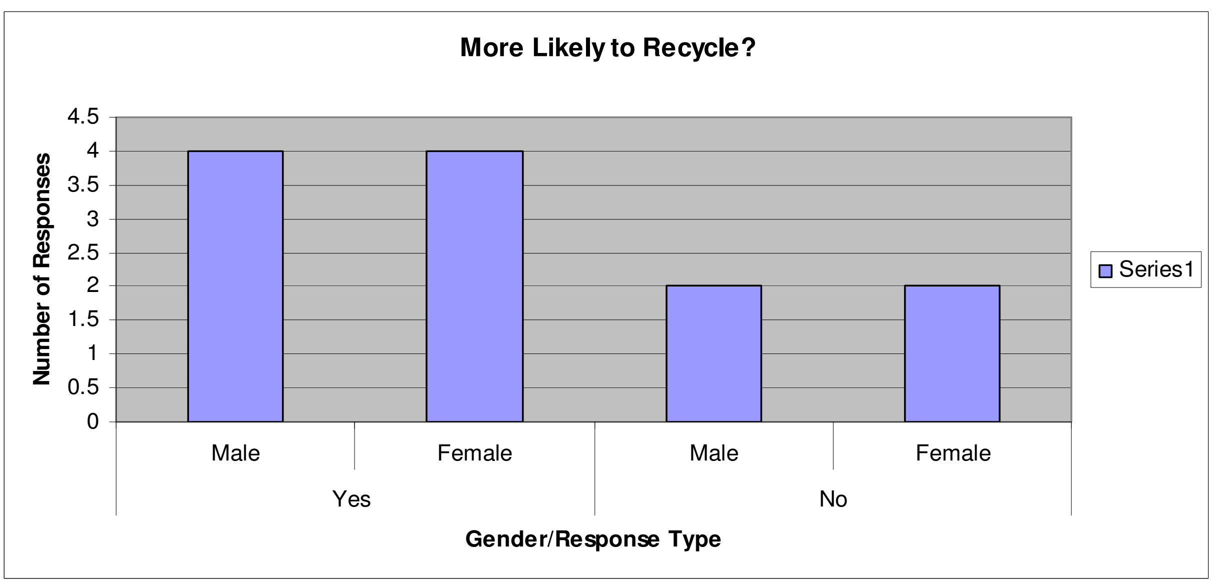

Figure 14: Experimental Data, Question 8

Survey

Based on your observations, what can you determine about the function and/or purpose of this product?

1) Based on your observations, is this a container in which trash should be disposed?

Yes No Not Sure

2) Based on your observations, is this a container in which recycling should be disposed?

Yes No Not Sure

---

3) On a scale of 1-10, with 10 being very easy and 1 very difficult, rank the ease with which you completed the task.

1 2 3 4 5 6 7 8 9 10

---

4) On a scale of 1-10, with 10 being very easy and 1 very difficult, rank the ease with which you completed the task.

1 2 3 4 5 6 7 8 9 10

5) On a scale of 1-10, with 10 being a very high amount and 1 a very low amount, rank the amount of strain felt when completing the task.

1 2 3 4 5 6 7 8 9 10

6) Do you feel the recycling/waste disposal process is easier with one of these products than it is with the other? If yes, please state which product you feel makes the recycling/waste disposal process easier.

7) Do you feel that owning either of these products would make you more likely to recycle than owning the other? If yes, please state which product you feel would make you more likely to recycle.

Appendix C

Question 3

Male:

```
                        N  Median
Generic Model           6   6.500
Ergonomic Model         6   9.500


Point estimate for ETA1-ETA2 is -3.000
95.5 Percent CI for ETA1-ETA2 is (-6.000,-1.000)
W = 22.5
Test of ETA1 = ETA2 vs ETA1 < ETA2 is significant at 0.0052
The test is significant at 0.0043 (adjusted for ties)
```

Female:

```
                 N  Median
Generic Model    6   4.500
Ergonomic Model  6   9.500


Point estimate for ETA1-ETA2 is -5.000
95.5 Percent CI for ETA1-ETA2 is (-6.000,-2.999)
W = 21.0
Test of ETA1 = ETA2 vs ETA1 < ETA2 is significant at 0.0025
The test is significant at 0.0023 (adjusted for ties)
```

Question 4

Male:

```
                 N  Median
Generic Model    6   7.000
Ergonomic Model  6   8.000


Point estimate for ETA1-ETA2 is -1.000
95.5 Percent CI for ETA1-ETA2 is (-3.000,-0.000)
W = 25.0
Test of ETA1 = ETA2 vs ETA1 < ETA2 is significant at 0.0153
The test is significant at 0.0100 (adjusted for ties)
```

Female:

```
                 N  Median
Generic Model    6   5.500
Ergonomic Model  6   9.000


Point estimate for ETA1-ETA2 is -4.000
95.5 Percent CI for ETA1-ETA2 is (-6.000,-3.000)
```

```
W = 21.0
Test of ETA1 = ETA2 vs ETA1 < ETA2 is significant at 0.0025
The test is significant at 0.0020 (adjusted for ties)
```

Question 5

Male:

```
                  N  Median
Generic Model     6   4.500
Ergonomic Model   6   2.500


Point estimate for ETA1-ETA2 is 3.000
95.5 Percent CI for ETA1-ETA2 is (0.999,3.999)
W = 55.5
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.0052
The test is significant at 0.0044 (adjusted for ties)
```

Female:

```
                  N  Median
Generic Model     6   6.500
Ergonomic Model   6   3.500


Point estimate for ETA1-ETA2 is 3.000
95.5 Percent CI for ETA1-ETA2 is (2.000,4.000)
W = 57.0
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.0025
The test is significant at 0.0023 (adjusted for ties)
```

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