Global Product Design / Engineering

Design Review 3

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Executive Summary

World Innovative Technologies, Inc. (WIT) is a multinational consulting company with offices in Michigan, USA, Berlin, Germany and Seoul, South Korea. Team Dynamic Crush is a division of World Innovative Technologies that concentrates on resolving global ecological concerns. The Team has been assigned the task of determining ways in which the concept of a closed loop economy promoting sustainability can be achieved by using the internet.

With this in mind, the team identified the need for creating a system that will counteract the current reduction in world wide aluminum can recycling rates. The team proposes to create an internet ready appliance that will promote aluminum can recycling. This appliance consist of a can crushing mechanism (to make it easier to transport numerous cans in bulk to a recycling station), and an electronic system that logs the number of cans recycled by an individual on an online database and hence to an online social community that tracks the users progress. Each aluminum can recycled translates into a reward token on “Canbook” (the online community). These reward tokens serve as a motivational tool, as they can be exchanged for many items, amongst which are discount coupons, lottery tickets, or donations to a local charity.

With this idea in mind, the team proceeded to follow a structured engineering analysis en route to developing the final product solution. The team highlighted different customer requirements, and proceeded to create the product as a global platform for its primary market in the US, and its secondary market in South Korea. Product engineering consisted of matching the customer requirements to the correct combination of proposed design alternatives that were based on numerous functional analyses. Detailed engineering analyses followed after determining the correct combination of an internet ready appliance that would satisfy the target market. The final proposed solution consisted of an automated can crushing device with numerous sensors to identify the input material, the input weight, the count of the number of cans crushed and the emptiness of the waste disposal basket. The proposed solution made use of an internet ready kit that logged all of these statistics to an online database, and the Canbook tool.

The next stage of the process consisted of converting the theoretical model into a proof of concept prototype. The team proceeded to procure the necessary components that would emulate the functions needed to be completed to demonstrate an internet ready appliance. There were many key differences between the proposed design and the end prototype. These consisted of a manual method to crush aluminum cans; a weight scale to determine if a can was empty prior to crushing; a proximity inductor to determine if the can was aluminum, or a foreign object; and ultrasonic wavelength sensors to count the number of cans crushed, and determine when the storage bin had to be emptied.

To conclude the process, the team predicted an estimate retail price for their proposed solution when released in each respective market. Since the product is intended for more individual use in the primary market, the team was able to take advantage of large economies of scale and place a price tag of $150 per unit. Since this can crushing device was designed to cater to populated building locations in the secondary market, its sheer size and lack of any economies of scale (due to low unit sales numbers) resulted in an expected unit cost of approximately $2500.

Introduction

World Innovative Technologies, Inc. (WIT) is a multinational consulting company with offices in Michigan, USA, Berlin, Germany and Seoul, South Korea. WIT has successfully been in business for over ten years. With an increasing number of personal computers in households, there is high potential growth in developing internet ready appliances[1]. The internet ready market is saturated with home automation and digital media: thus, a competitive advantage is found through engineering sustainability relevant to a closed loop economy. WIT is committed to offering innovative engineering solutions for the global market[1].

Team Dynamic Crush is a division of World Innovative Technologies that concentrates on resolving global ecological concerns. Dynamic Crush was established in September of 2007. Dynamic Crush is able to meet the demands of WIT's vision through its global team of six engineers. Three engineers have focused their studies in robotics, mechanics and airplane engineering, and have a vast technical understanding of the mechanical dynamics. These engineers lead the research of the functional aspects of the project. There are two industrial and one manufacturing engineers who have practice integrating the technical needs with the industrial needs of manufacturing and mass production. Our team members are experts in writing well structured reports with strong skills in Office applications. There are three artists with one specializing in Photoshop who finesses many drawings and presentations into professional quality. These talents enable the team to effectively visualize key points and communicate their ideas to a broad audience. These diverse talents from the team members promote a well organized, robust and successful design project and design team.

Needs Identification

Global needs were identified through brainstorming within the team. The top five needs were identified and were further researched. Dynamic Crush selected the needs for light sources, refuse collection, aluminum can recycling, automobile driver-fatigue monitoring and clean water delivery. The entire feasibility study can be found in Appendix A.

From the feasibility study, the recycling need was determined to be the best idea aligning with WIT's global goals and meeting both customer and team constraints. The initial market study revealed a need for increasing the percent of aluminum cans recycled relative to sales of aluminum cans. The US market percentage of aluminum cans recycled over the period from 1994 to 2004 has significantly decreased[2]. In the Korean market, we have seen that a relatively small amount of aluminum cans are recycled[3]. Given the high level of monetary, environmental and energy savings that are achievable by recycling aluminum cans[4], the team chose to further develop the aluminum can recycling machine into a global, internet ready product.

A study on the average American consumer reported that the number one reason (33%) for lack of recycling is laziness. The second reason for lack of recycling (21%) was attributed to inconvenience[5]. The team hypothesized that if recycling was easier to complete and did not take much more time consumers would actively participate in recycling.

Problem Statement:

"*Increase consumer participation in recycling aluminum cans through awareness, availability and internet application.*"

This global product will enable a closed loop economy by reducing the waste of materials and energy; recycling aluminum cans; and reusing material. The internet application will encourage consumers to increase their recycling rates through an online community.

Market Analysis

Market Size

The two markets that the team targeted consist of consumers residing in the US and in Korea. The team judged the market size based on the expected number of people that would purchase such a product, and then the number of expected units to be sold within each market. Furthermore, the target market in the US consisted of individual purchasers, whereas the Korean market consisted of community purchasers. Based on this, the US market for this product was expected to be at four million households, translating into four million units of this product being required[6]. The Korean market consists of 45,000 communal units[7]. Based on the market size, the US market will be the primary market with South Korea as the secondary market. Detailed assumptions and market size estimations are found in Appendix B.

Customer Requirements

The requirements from each market have both common and market specific components. A complete market analysis can be found in Appendix C. Figure 1 below depicts the storyboard for the internet recycle machine promoting a closed loop economy. The customer consumes beverages in aluminum cans that have various shapes in each market. Once the can is empty, the customer recycles the can at a communal or private recycling machine. The recycling machine crushes the can and counts how many cans have been deposited by the customer. A signal is sent through the internet to a website that records recycling history. Each time the consumer uses the machine they increase the recycling statistics for their area. Furthermore, the customer earns money for each can they deposit and are entered into a drawing for prizes. The customer is happy because they are helping to keep the environment clean and feel satisfied. When the container is full, a signal is sent through the internet to empty the container. For the communal system, a recycling company empties the bin. For the personal unit, the customer collects the crushed cans to be picked up. The recycling center receives the crushed cans and reuses the material to make new aluminum cans. The loop is closed when the customer purchases a recycled can.

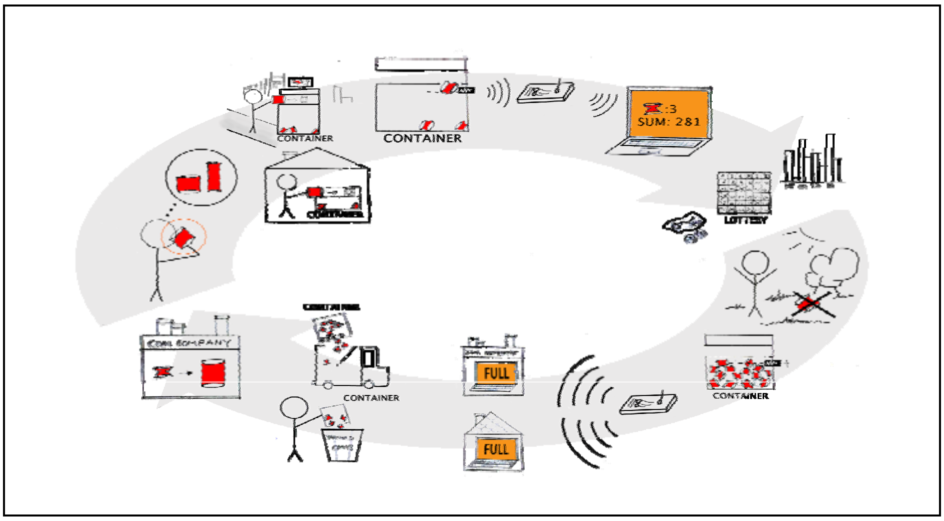

Figure 1: Closed loop customer use storyboard.

Global Platform

The product design is a global product in that there are similar functions for both the US and Korean markets. The mechanism for inserting the empty can, and for counting and sensing the level of cans in the bin are the core components for both markets. The method for crushing cans and the bin size is specific for each market. Figure 2 shows a Venn diagram that depicts the similarities and differences between both markets.

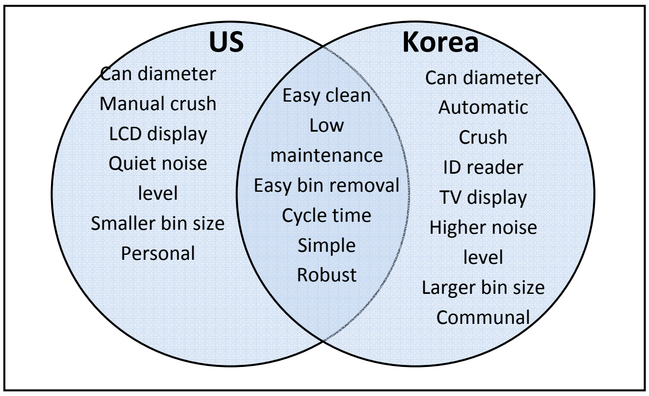

Figure 2: Venn diagram for comparing global market needs.

Competitor Benchmark

The concept of crushing cans has been around for several decades. Individual can-crushing products currently exist on the market, but are more of a static system. The difference with our product is the ability to combine a crushing mechanism with a dynamic storage container that records how many cans have been crushed, and when the container needs to be emptied. Research shows that no can-crushing product with an internet capability currently exists on the market, or has been developed as concepts in the past.

Patent Search

The patent search on existing can crushing devices revealed that there are many existing ways of crushing a can. Several different methods ranging from manual to automatic systems are used to crush a can. Some crushing mechanism found consisted of hand operated, foot operated, motorized and pneumatic methods. A summary of the different patents mimicking our product concept can be found in Appendix D. While there were similar mechanisms, no patent currently exists that combines the can-crushing with the internet signal and bin level sensor. The focus of our design is to fully integrate an aluminum can recycling device with an internet networking website that utilizes sensors to increase can recycling rate worldwide.

Product Engineering

The online recycling center was further divided into a task clarification list where customer demands were paired with engineering metrics. The constraints were divided into demands that must be met under all circumstances and wishes that were taken into design consideration when possible. Table 1 on the following page outlines the requirement list with engineering specifications.

Table 1: Customer requirements list with engineering specifications.

WIT, Inc	Requirement list	2007.10.5
Dynamic Crush	for the Internet Recycle Machine	Page 1/1
D/W	Required functions and constraints	
D	Geometry Height must be comparable to standard cabinent height (99 cm) for US.[1]	
D	Height The input port should be at average Korean woman shoulder height (121 cm)[2]	
W	Noise The machine should be quiet (< 40 dB)	
D	Motion The machine should complete one cycle within 8 sec for automatic operation	
D	Force The force to manually operate crushing should be less than 20 N (4.5 lbf)	
D	Volume Must reduce volume of aluminum can for storage (80% reduction in volume)	
W	Cost Private unit must be affordable (< $ 150 USD)	
D	Material Must be corrosion resistant	
D	Stress Must be able to withstand stress in excess of 4500 grams (100 lbs)	
D	Safety Must not post danger to hand or limb	
W	Automation The machine should be automated requiring little human energy to crush can	
W	Maintenance The machine should have little operating costs and be of high quality	

Functional Analysis

The function of the internet recycling device was decomposed into functions using a black box diagram that relates all inputs to outputs, as shown in Figure 3. Further sub function analysis can be found in Appendix E. There are four sub functions for this project: crushing a can, sending a counting signal, dropping a can into the storage bin, and recording the bin fullness level.

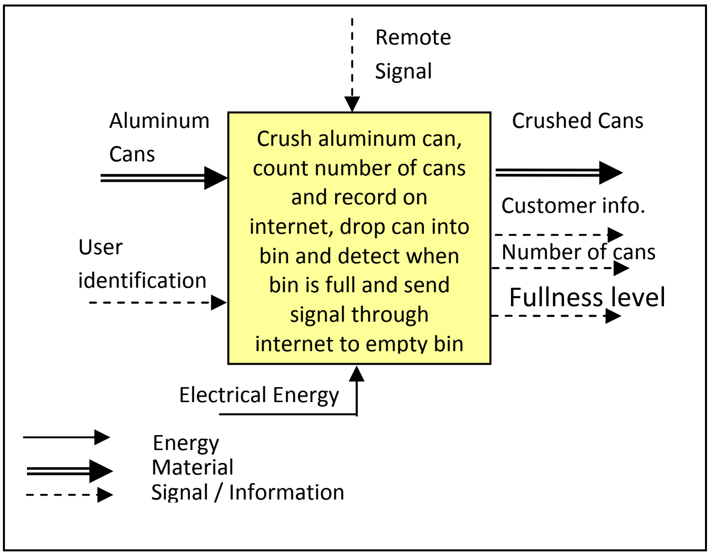

Figure 3: Black box diagram for online can recycling machine.

For each sub function, research on current and previous technology was utilized to create design alternatives, resulting in five alternatives to crush cans; five alternatives to count the cans recycled; four alternatives to measure the bin level and four alternatives to drop the can into the bin. A complete design alternative matrix with sketches is shown in Appendix E.

Design Alternatives

Design alternatives were created by combining one working principle from each sub function and integrating these principles to obtain a design alternative. From the number of working principles, 400 design alternatives are possible. Four design alternatives were selected for further research. The alternatives ranged from manual to automatic crushing mechanisms with a variety of counting sensors and bin level sensors. All design alternatives along with the design selection matrix can be found in Appendix F.

Design Selection

All four design alternatives were measured against customer criteria and given a rating from 1 to 10. A total score was determined by combining the weighting factor with the rating number. As a result, the top design alternative was design alternative 4. The complete design alternative matrix is in Appendix G.

Design alternative D was selected to meet the global customer needs. This design utilizes the light sensor to function both as a counting mechanism and a bin level sensing mechanism. The can loading mechanism utilizes potential energy and does not increase the component cost of the machine. The small number of moving parts results in a more robust design with less maintenance costs.

Platform Structure

While customer requirements differ within a global market, certain elements of the internet recycle machine remain the same. The elements that remain the same are the core elements of the design. Elements that are tailored to a specific market are design variations. The core elements and variations for recycling aluminum cans are listed in Table 2 below.

Table 2: Platform structure of global internet recycling machine.

Core Elements	**Variations**
• Crushing mechanism • Gravity feed mechanism • Internet signal method • Light sensor for counting & measuring	• Container size • Full container removal • Customer identification • Liquid removal

The variations in size are related to the number of customers that each machine serves. In the US, it is a personal unit in the home that is small. In Korea, it is a communal unit shared by over 200 people. With a larger customer base, the Korean variation is larger than the US variation by size.

Container removal varies due to the volume of each bin. The larger bin must be locked and is removed and collected by a recycling company in a large truck. The smaller bin is carried outside the house by the homeowner, for collection by the recycling company.

The customer identification variation is also due to the number of customers each unit serves. The home unit has a constant user and does not need to have an ID card to credit an account. The communal unit has many users that need to be identified for proper credit to their personal online account.

Since the aluminum cans have some liquid residue after crushing, the excess liquid will be captured differently for both markets. For the home unit, a drain bucket will be required. For the communal unit the draining system can be connected to existing drainage lines.

Closed-Loop and Internet Aspect

This product will enable a closed loop economy by reducing the waste of materials and energy; recycling aluminum cans; and reusing material. The internet application will encourage people to increase their recycling rates through an online community with various incentives.

The internet application enables the customer to participate in completing the closed loop economy by offering incentives to use the product. Each aluminum can recycled translates into one token that can be redeemed on the internet community called Canbook. Since all people do not have the same motivations, three incentives are offered with this product. For customers who want to feel satisfied in saving the environment, a recycling profile for comparison is available on the website. These customers can also donate their tokens to charities and display their donation on their profile. This aspect can encourage competition to recycle with others in the online community. For customers that like to gamble or take risks, the internet has a multiple drawings for online prizes related to the number of cans they recycle. The tokens earned from recycling can be entered into drawings for prizes. For customers that are motivated by monetary gains, money saving coupons to many local and national retailers can be redeemed using the Canbook tokens. Companies will sign up to participate in the program and donate the coupons. In exchange for their donation, the website features sponsors each month and has a "Marketplace" feature where the customers can access the company's retail website and use the coupon they have earned. Not only do the sponsors gain customers, they also promote an environmentally friendly image.

Everyone who owns a can crusher will be given access to an online community called "Canbook" where the customer can create a personal website similar to Facebook[8]. Each user has the option to make their account public and can select the layout of their page. During registration the user will input the can crusher information that will link the machine to their account. Once the connection has been established between the home unit and the user account, each time a can is recycled using the machine, a signal is sent through the internet kit to the user account. Screenshots of Canbook can be found in Appendix H.

Canbook also offers four incentives for users to increase their recycling rates: eco-friendly image and competition; lottery drawings; valuable coupons from retailers; and the option to donate their rewards to charity. As the concern for the environment rises, so does the need for people and businesses to promote "green" thinking.

- Eco-friendly Image

The Canbook website allows both people and businesses to accomplish this goal. Businesses can participate in the program by deciding to sponsor the project. Sponsorship includes donation of valuable coupons for their services and a monetary donation to the website. In return for sponsorship, the company will be listed under sponsors and a direct link to their retail website will be listed under marketplace. Here, companies are seen as being eco-friendly: they increase their customer base with advertising, and have greater interest in their online retailing through money saving coupons.

For the consumer, the Canbook website tracks and displays the number of aluminum cans recycled for each account. This number is translated into energy saved and reduction in landfill volume. These statistics can be shared with all Canbook users if desired and give the account holder an eco-friendly image. With Canbook, friends can be added to the account and the user can participate in online competition. The account holder can compare their recycling count to the average for their city, state or worldwide statistics. The online friendly competition can encourage users to not only recycle the cans they have purchased, but to collect cans from others or pick up discarded cans littering their surrounding environment.

With each can recycled, the account holder earns one token. These tokens can be donated to charity through Canbook and the donation can be displayed on the user's account. This will allow the user to help others, promote a great charity and promote a philanthropic image for the user.

- Lottery Drawings

Lottery drawings are also held within the Canbook community. For each aluminum can recycled, the account holder is given one token that can be redeemed for tickets in weekly and monthly drawings. The lottery prizes are donated or purchased from business sponsorship. This system's goal is to motivate users to recycle 100% of their aluminum cans bought and to encourage collection of discarded cans from their neighbors and the community.

- Coupons
  Tokens earned from recycling cans could be redeemed for valuable coupons from local and national retailers. Depending on the account holder's preference, coupons donated from sponsors can be redeemed. The account holder is also directed to the marketplace after redeeming a coupon for online shopping.

- Donation
  The Canbook tokens can also be donated to charities through the website. Certain customers do not want any monetary gain from the system but want to help others in need. The donation option allows the account holder to donate the tokens to a charity and Canbook will make a monetary donation to that charity. This allows account holders to not only help the environment but also help others that are less fortunate.

Customer Interface

The customer interface with the machine requires more that simply placing a can in the device. Once the customer places a can in the machine, the system must determine if the can is aluminum, determine if the can is empty, send a count signal for every crushed can, and monitor the level of recycled cans in the bin. A flow chart of the customer interface can be found in Appendix I. The system does two checks before allowing the can to be crushed. The first check is to determine if the object is aluminum. Once the can is determined to be aluminum, the system must decide if the can is empty. Crushing a full can is not encouraged because it can explode, damage the electric motors and cause a sticky mess for the customer to clean up. After the can passes both check points, the decision door is opened allowing the can to proceed to crushing.

After the can is crushed, two readings are required from the system to be sent through the internet kit to the system's website. The crushed can is counted using an infrared reflex barrier. This device creates a counting signal when an object breaks the light beam. This counting signal is sent to the internet kit and recorded to the website. The website tracks the number of crushed aluminum cans and can be accessed by the customer. The second reading that is required after crushing is the level of cans in the recycling bin. To determine the level in the recycling bin, a digital weight scale is used. A simple experiment to determine the weight at different volumes results in weight thresholds for different levels: empty, 25%, 50%, 75%, 90%, 95% and 100% full. When the recycling bin is full, the internet kit sends a signal to the website which sends a reminder to the customer to empty the bin and take their cans to the nearest recycling center. The customer can preset their preference on either cell phone text messages or email messages.

Engineering Sub Functions

There are four sub functions for this project: crushing a can, sending a counting signal, dropping a can into bin and recording the bin fullness level. The most relevant and innovative functions related to the project are the internet integration using a combination of a counting signal and a bin fullness signal. Since many solutions to crushing a can exist, this design focuses on incorporating the internet into the crushing machine. This is done with many sensors that must communicate within the device and with an internet kit.

The device must be robust enough to detect if a foreign object is placed in the machine; if a full or partially full aluminum can is placed in the machine; count how many cans have been recycled; and determine the level of recycled cans in the bin. To complete these requirements four sensors are necessary: material wavelength sensors, strain gauges, ultrasonic wavelength sensors and digital weight scales respectively.

The wavelength of materials is unique and a simple sensor that measures material wavelength is used to determine the objects material. The sensor determines if the wavelength of the object corresponds to aluminum. If the wavelength is that of aluminum, the object moves to the next step in the crushing process. If the object is determined to be foreign, the removal door will illuminate so the operator can remove the object from the machine. It is important to determine the composition of the material to be crushed. If the material is rigid and requires greater force to crush, the electric motors could fail or require replacement before the life cycle of the product. Since the customer is being rewarded for recycling aluminum cans, measures to ensure the system can not be defeated are required. The wavelength sensor ensures that the object can only be crushed and counted if it is aluminum. This will prevent customers from abusing the system by placing foreign objects in the system for reward.

The liquid level in the aluminum can is determined prior to crushing. For this requirement, strain gauges are used to determine the can weight. Strain gauges measure deflection on a surface. Since the object is placed into the machine and rests on the decision door, the deflection of the decision door can be measured. The threshold levels can be determined from a simple experiment. Measure the strain gauge reading for an unopened can, an empty can and a can with one ounce volume. With these readings, a simple program can be made to reject the can if the strain gauge reading is above the threshold. If the can is determined to be empty, the process continues. If the can is measured to be above the threshold level, the removal door will open so the operator can remove the can and empty as necessary. There will still be some residual liquid left in the cans after crushing. To capture this liquid a mesh screen and liquid tray are used. Since this function is not the focus of the design, a simple grate and tray were selected. There exist many alternatives to collect waste liquid; however, engineering resources were not spent on determining the optimal solution since this function is not the focus of the design.

The internet reward website requires the exact number of cans recycled to be counted. To complete this task, an ultrasonic wavelength sensor is required. This type of wavelength sensor is located below the automatic crushing device and sends a counting signal to the internet kit when a crushed can falls from the crusher onto the liquid removal mesh. The ultrasonic wavelength sensor is a simple device that is wired from one side of the unit, and sends a different signal every time its base wavelength signal is broken by a falling crushed can.

The final sub function of the device is in measuring and recording the weight of cans in the recycling bin. The bin has a mesh drawer that holds a trash bag for recycled can collection. The bag of recycled cans should be removed and taken to a recycling center when it is full. If the bag is not monitored it could be removed too frequently (resulting in a waste of plastic bags) or not often enough (resulting in a heavy plastic bag that could break under the weight of the recycled cans). To allow the customer to optimize the recycling bin, a digital weight scale is placed in the bottom of the drawer to monitor the weight of the recycling bin. The fullness percentage is transmitted through the internet kit to the user account. When the bin is full a reminder is sent to the customer to remove the bag and take it to the recycling center.

Engineering Analysis

The key studies on the proposed design consisted of basic engineering analysis to determine if the design is feasible to crush a can, to sizing the rotary crushing wheel and motors, to determining if specific types of sensors are commercially available. We conclude that our design is indeed feasible as a number of the parts going into our system are commercially available. The essence of our product lies not necessarily in the way our system crushes the cans, but the way in which our system is able to interact with the user and with the internet.

The team created a set of assumptions in determining the motor requirements to crush aluminum cans. Based on these assumptions and an appropriate safety factor, the approximate power rating of each motor to rotate the crushing mechanism is 0.5 hp. Team research on motors (Appendix L) shows the assumptions, calculations and motor manufacturers for this application.

Using the geometry of an aluminum can and the assumption of 80% volume reduction after crushing, the rotary wheel's gap, radius, rotary break length and thickness were designed. Appendix M contains the exact assumptions and calculations for the rotary wheel.

The overall size of the unit was determined by benchmarking our proposed design to existing recycling and trash bins that are commercially available for home use[9]. Based on this, overall dimensions of our product (length, base, height) were determined to be 520mm × 520mm × 1100mm. With this in mind, the drawer for the recycled cans was designed to hold approximately 30 aluminum cans. A complete list of assumptions and calculations can be found in Appendix N.

As mentioned in the BOM, the types of sensors that the team wishes to use consist of strain gauges to determine the 'fullness' of the can; material wavelength sensors to determine the material of the object placed into the system; ultrasonic wavelength sensors to count the number of cans crushed by the device; and a platform weight sensor to determine when the storage unit needs to be cleaned out. Research on each of these types of sensors shows that they are available commercially, and that they can achieve the tasks that wish to be completed. Furthermore, these sensors have the ability to interface with an internet communication kit that allows the team to create an internet ready, closed loop system. Appendix O highlights the research on each of the sensor components.

Product Manufacturing

The bill of materials (BOM) for the can crusher was created for the primary market and can be found in Appendix J. The BOM lists 16 items that are required for the personal crushing unit. The crushing unit has two sub-assemblies: automatic crushing and drawer assembly. The automatic crushing assembly is the most intricate and has 10 different parts required. The drawer assembly has three parts. The BOM also calls for a liquid storage tray, an internet kit and shell housing. The automatic crushing assembly is composed of stainless steel to prevent corrosion from the can liquids. This assembly contains all electric motors and three out of four sensors. The drawer runs on a track and has a digital weight scale to monitor fullness.

The BOM was then separated into parts that composed the global platform and area specific parts. The global platform consists of parts that are shared by both the primary and secondary markets and contained 9 out of the original 16 parts. All the sensors, motors, internet kit, rotary wheels and shafts were part of the global platform. The primary market has a removable drawer, liquid trap and core that are similar to the secondary market. A table showing the platforms and estimated prototype BOM can be found in Appendix K.

Mass Production Manufacturing Details:

There is numerous production processes required to create an interactive can crushing system that will be intended for the primary market. Sheet metal stamping and bending will be used to create a variety of different parts associated with the ideal crushing unit. These pieces include the core of the crushing unit; the shell; and the necessary housing units to support the motors and sensors. Aluminum or steel die casting will be used to create the rotary wheels as they have to be solid with flush edges so as to secure the can prior to actual crushing. The connecting shaft between the rotary wheels and the motor will be created via metal extrusion processes. The three doors in the ideal product will be made of plastic and manufactured via injection molding.

Given the lack of maturity of interactive aluminum can crushing units that exist in the market today, the initial mass production plan will consist of an all assembly process: components will be outsourced but assembled at the facility. Assembly is expected to be a highly labor intensive process. All of the key components of the end unit (including motors, sensors, gages, inner and outer cores, rotary wheels, storage baskets, drawer rails, and supporting housing units pieces) will be outsourced to OEM companies, thus taking advantage of avoiding capital expenditure on various mass production methods such as die casting, injection molding, and sheet metal stamping and bending machines. Each assembly center will be responsible for procuring the necessary parts to assemble each unit (based on initial and future forecasted product demand), and then physically assembling and testing each unit prior to end deliver to the customer.

The supply chain for both the primary and secondary market products consists of having both part production and assembly within each specific region. The procurement of parts and system assembly of the household crusher will take place with in the US, with a similar situation for the commercial version in Korea. This system was selected to take advantage of lower lead times, avoid excessive tariffs and governmental barriers associated with international shipments, and incur very few international shipping costs in transferring raw materials and finished products to the end customer market. This results in the assembly center in each market being more responsive to the market needs, and thus contributes towards better cycle and safety inventory control at site.

Prototype

The final prototype of our proposed design consists of a physical model that mimics an internet ready, closed loop device for the primary market. Although there are many differences between the proposed design and the final prototype, the key elements of crushing aluminum cans and recording recycling information via the internet is still maintained and demonstrated. The innovative elements of the design include: the counting sensor, the internet kit and aluminum detector.

Crushing Mechanism

The crushing mechanism differs from the design in that it is a manual process of crushing the beverage can. The automatic crushing units are common in commercial recycle machines and are not novel in its design. The time and monetary constraints also led to the manual crushing selection. The prototype crushing system consists of a metal plate that slides in a horizontal path, crushing the can against a stationary wall. Appendix P shows a picture of our crushing mechanism. The crushing mechanism was procured at a hardware store called Stanton's in Alvin, Texas, and shipped to Michigan. The team customized the crusher by machining out an exit hole for the crushed can such that gravity will drop the can directly into the storage bin. The original system was vertically mounted and the prototype horizontally mounted the crusher.

Inner & Outer Core

The inner and outer cores of the proposed solution are demonstrated with a pre-assembled wooden dresser that serves to support the can crusher, the different sensors, the storage unit and the liquid collection tray. The box was purchased at Bauhaus in Berlin because it could not be shipped due its bulky size. The outer box is made of 1” thick oak that held six drawers. The drawers were removed to allow ample room for the sensors. Appendix P highlights the supporting box structure. A hole in the top part of the box was machined such that the manual can crusher can be secured, and allow the aluminum can to fall directly into the storage unit after crushing it. To allow extra space on the top of the box, sections of wood from the drawers were affixed to the top using 2 ½“ L-brackets.

Mesh Drawer and Liquid Storage Unit

The storage unit and the liquid storage unit of the proposed solution are demonstrated by a plastic mesh storage box, and a simple plastic tray, respectively. These items were purchased in Berlin at Bauhaus. The mesh storage box utilizes the wooden track for the drawer to slide in and out of position. To demonstrate the drainage properties of the design, 3/8“ holes were drilled around the edge of the tray to allow draining. The plastic tray is positioned at the bottom of the box such that excess liquid from a crushed can falls directly into the tray. Appendix P highlights these two storage units.

System Sensors

There are four types of electrical devices that perform different the different system functions as required by our proposed design. These functions consist of determining whether or not the can is empty; whether the can to be crushed is made of aluminum; counting the number of cans crushed; and determining when the storage unit needs to be emptied. Appendix P highlights the different sensors used in the final prototype.

- **Digital Scale:** A digital kitchen scale was used to determine if an aluminum can was empty prior to crushing. To set the decision criteria, an empty can was measured and a can with less than 1 ounce of liquid was measured. As a result, if the can is greater than 35 grams, the can should be emptied. If the can is less than 35 grams, the can passes on to the next station.

- **Inductive Proximity Sensor:** The inductive proximity sensor is used to tell whether the placed can is made of aluminum. This sensor has an inductive loop that generates a magnetic field when detecting metals. The voltage output of the sensor varies with each type of metal. The sensor and power pack were purchased rsonline.com and shipped to Berlin. The cost for the power pack and sensor was approximately $130 USD.

- **Ultrasonic Wave Sensors:** Two sets of ultrasonic wavelength sensors are used to count the number of cans crushed, and determine when the storage unit needs to be emptied. To determine the number of cans crushed by the user, the sensor is placed just under the top surface of the supporting box. As the crushed can falls through, the wavelength sensor detects a change in time taken to send a signal back and forth to a receiving unit as a result of the can breaking this wavelength path, and sends a pulse to the processing unit and to the internet kit to count that one can has been crushed. Similarly, two wave sensors are mounted to the wall of the wooden box near the top of the removable mesh drawer. As the number of cans pile up, it reaches a point at which the path of the signal from this sensor is continually broken. As this happens, the sensor sends a signal to the internet kit, which alerts the user that the basket has to be emptied.

- **Internet Kit:** The internet kit is physically attached to the prototype, and is connected to an external computer for the processing of information. The kit is used to take in the input signals from the ultrasonic wave sensors to clock in the number of cans crushed, and the alert the user when the storage bin needs to be emptied out.

Differences between Actual Design and Prototype

There are many differences between the actual design and the prototype. The rotary, automatic can crushing system was replaced with a hand crushing unit, as the novelty of the proposed solution is not the way in which a can is crushed. Furthermore, inner and outer core units were replaced with a simple wood structure as the main purposes of these pieces is to provide support for all the components in the proposed design. This decision eliminated the need to work with sheet metal that would otherwise be expensive to stamp, machine and assemble.

The geometric differences in scale are due to the availability of the wooden dresser and plastic bins. Since the decision to purchase housing components was made, the shape of the prototype is smaller than the design. The bin removal system is different from the design in the prototype. The design is a metal track with plastic rollers similar to filing cabinets. The wooden design was chosen due to the selection of the wood dresser. The design required the crushed cans to slide down a mesh grid before entering the bin to remove excess liquid. The prototype removed the excess liquid after the cans were in the bin.

Other differences lay in the placement of the strain gages and the aluminum can recognition sensors since this provided a method of clearly visualizing the process flow path prior to the actual can being crushed. This also eliminates the need for the removal door, as proposed in the original design. The digital weight scale and the reflective barrier sensors have been substituted with a set of ultrasonic sensors to determine when the storage unit needs to be emptied and to count the number of cans crushed as it was determined easier to use and interface with the internet kit.

An inductive proximity sensor to detect the aluminum content is the same as the design requires. The final design would analyze a voltage signal to determine the metal composition. For the prototype, a light on the sensor illuminates if any metal is placed on the sensor. The limitations of the human eye do not allow the resolution of the signal, however if connected to a central CPU the signal could be detected. For the prototype a green light illuminates when any metal is touched to the sensor.

BOM for Prototype

Appendix Q highlights the BOM for final prototype. The subassemblies have been regrouped to represent can crushing; system housing; drawer assembly; can counting; determining can material and 'emptiness'; and internet communication. A majority of the parts in the BOM have been purchased ready made, or were modified by the team to demonstrate the ideal closed loop can crushing system. Items to create the prototype were sourced based on the local availability and lower economic cost. The can crushing mechanism was only available in the US at a relatively low price, and was thus obtained and modified in the US. The different sensors and internet kit were sourced from OEMs in Korea due to the abundant availability and cheap local price. Bulk items such as the wood and plastic to make system housing and the drawer assembly were obtain from Germany simply due to sheer size and availability.

Manufacturing Assembly Plan

It is expected that the mass production of the ideal solution is highly labor intensive. This was no exception towards the prototype for the proof of concept. The first part of the process consisted of programming the internet ready kit to accept input signals from the wavelength sensors, and then pass these signals over to the computer and update the respective website. Next, the assembly consisted of configuring the proximity sensor and the strain gage to ensure that the correct cans could proceed for crushing. Concurrent with sensor configuration was the machining and assembly of the system housing and the can crusher. The final assembly process consisted of putting all of the components to build the final internet ready, can crushing unit.

Business Plan

This section proceeds to highlight the business plan for what the team expects in terms of launching and sustaining its product. The first analysis carried out was predicting a rough estimate of the number of users of this product within each market. Next, a cost-based pricing method was used to determine the expected price of the proposed product within the respective market. Finally, different distribution and launch strategies were considered for each market.

Primary Market: USA

Target Sales Volume: The target sales volume in the US is expected to average at approximately four million individual households per year. This number is based on assuming that half of the average population in the most populated cities (see Appendix B) will use this product.

Product Manufacturing Costs: The product manufacturing costs consisted of the fixed and variable costs that would be incurred in satisfying our target sales volume. Appendix R shows a detailed analysis of the fixed and variable costs in producing the Dynamic Crush can-crushing unit, along with the specific assumptions into economies of scale to determining the price of each can crusher. The total product manufacturing costs per unit is determined to be approximately $98 per unit, with the entire procurement of parts and assembly of final product taking place within the primary market itself.

Product Price: The team assumes that a conservative markup of 50% will be used in pricing the final product to the primary market. This results in a price of approximately $148 for the entire unit with internet kit. This price assumes that there is no fee associated with using the online interface for final proposed solution, and does not take into consideration any warranty fees associated with the product.

Marketing & Distribution Strategies: The marketing strategy for this product is based on the core inspiration for creating this product: an interactive system that promotes the recycling of aluminum cans as a sustainable means for preserving energy. Marketing this product will predominantly consist of making the general public aware of this product; getting buy-in from local governments to promote this product use; and getting sponsorships from numerous different industries to contribute towards supporting the product. The idea of getting buy-in from local governments and large corporations is to have our product be used as a tool for advertising certain brands or community responsibility, and hence incur the cost of purchasing our product by allowing rebated machines to individual households.

With respect to the individual household, the crusher will be marketed as product that essentially pays for itself through recycling aluminum cans: the more cans that are recycled, the more ‘rewards’ are collected that can be redeemed for a multitude of options. These include discount coupons at different products from various stores (such as electrical appliances from a Best Buy, or consumer goods from a Target store); discount rates for particular kinds of services (discounts for tax return fees, or reduced rates for airfare with certain airlines); to different options of giving these rewards to the individual's charity of choice as monetary donations.

The distribution strategy is multifaceted with distributions in retail outlets and internet ordering. The initial method involves partnering with national retail outlets that are predominantly located in US states where no refund is currently offered for recycling cans. These states were selected because they currently do not have a mandated recycling program and will serve as a test market. There will be a floor model with an interactive video explaining the many benefits of the products. Feedback from these starter markets will allow the product to evolve and build evidence to bring this product into states that currently use a deposit system. As consumer awareness grows and there is ample evidence for state sponsorship the market will grow to replace deposit systems. The distribution strategy is expected to evolve into more of a Dell Direct Model, where customers themselves can place orders for the product directly from our warehouse. The internet application will be distributed through the internet itself, along with promotions through different sponsoring companies and local governments.

Secondary Market: South Korea
Target Sales Volume: The target sales volume within the South Korean market is expected to be 45,000 units that will be used by large building communities. This number is based on assuming that only the key metro cities in Korea will use this product in areas that are highly populated (see Appendix B for the methods in determining the number).

Product Changes: There are few, but essential product changes between the proposed solution to be marketed in the primary market and that in the secondary market. The first change revolved around the idea of size and scalability, in that the product in the secondary market is expected to be used by numerous individuals residing in populous areas. The result is fewer, but much larger and more robust solutions being needed to satisfy the consumer base, which in this case is expected to be tenants in a residential complex. Further changes required will be the way in which the system recognizes a user and individual account. Thus, the expected changes to the product will be a larger housing system and collection bin that will be expected to be made out stronger materials. Furthermore, a RFID card recognition system associating the individuals recycled cans to her account will need to be installed on the product. The core components of allowing cans to be crushed, and crushing them, will remain automated and unchanged. The aesthetics are not expected to change with respect to the product for the primary market.

Product Manufacturing Costs: The product manufacturing costs consisted of the fixed and variable costs that would be incurred in satisfying our target sales volume. Appendix R shows a detailed analysis of the fixed and variable costs in producing the Dynamic Crush can-crushing unit, along with the specific assumptions into economies of scale to determining the price of each can crusher. The total product manufacturing costs per unit is determined to be approximately $1,670 per unit, with the entire procurement of parts and assembly of final product taking place within the secondary market itself.

The approximate twenty-fold difference in the cost per unit between the primary and secondary market is predominantly due to the higher expected material and component costs in the secondary market. The savings in labor costs in the secondary market are not enough to offset the material and components costs. Since the product has to be larger and more robust for mass use in the secondary, this further adds onto the product unit cost. Finally, since the target volume in the secondary market is approximately 100 times less than that of the primary market, it is expected that the local manufacturing will be unable to take advantage of the economies of scale experienced by that in the primary market.

Product Price: The team assumes that a conservative markup of 50% will be used in pricing the final product to the secondary market. This results in a price of approximately $2,500 for the entire unit (the automated crushing system, recognizing when a can is aluminum and if it ready for crushing, and the internet communication kit). This price also assumes that there is no fee associated with using the online interface for final proposed solution, and does not take into consideration any warranty fees associated with the product.

Marketing & Distribution Strategies: The marketing strategy for this product is essentially to promote aluminum can recycling in developing regions of the world where this sort of energy savings method may not be quite as popular as other methods (or in some cases, where other methods do no exist). The end customer of this product is an individual who resides in a populous residential tower within the metro cities of the secondary market. However, the key persons who will be expected to purchase this product are those who manage populated residential complexes and local governments as the product is designed for large scale commercial use in the secondary market. The reward strategy as defined in the primary market will be the same as that in the secondary market: give the end user (the individual) further motivation to promote recycling of aluminum cans.

The distribution and launch strategy within the secondary is different from that in the primary market in that the team will aim the product at those who ‘manage’ communities (building management, or local governments). The product will not be sold through any commercial retail stores, but will instead use a more a personal approach in contacting potential customers and selling the product directly to them. Furthermore, the launch strategy will consist of obtaining sponsorships from local industries and government with the idea that this product provides a vehicle of advertising their own product or service in populated regions of a city. Launch for our product in the secondary market is expected to be concurrent with that in the primary market. Since the product is being purchased for mass scale in the secondary market (as opposed to household use in the primary market), trends from the primary market are not expected to predict those in the secondary market.

Project Summary

Objective Completion

Dynamic Crush intends on delivering a physical prototype to WIT that demonstrates the final design concept of a recycling bin that promotes a closed loop economy via the internet. However, due to monetary and time constraints, the mock prototype differed from the proposed design. A manual system of crushing cans will be demonstrated in lieu of an automated rotary style of crushing cans due to monetary and time constraints. This manual system will be derived and used from existing home can-crushing units. The final prototype structure will be built out of goods found in hardware stores (such as trash bins and plywood) as it will be difficult to injection mold and machine the respective plastic and metal components of our product. Furthermore, the online interface in itself will be very basic as composed to our proposed design: it will consist of a simple screen that counts the number of cans recycled and records the storage capacity available. The prototype will use the previously mentioned sensors to demonstrate the uniqueness of the Dynamic Crush product.

WIT, Inc	Requirement list	2007.12.7	
Dynamic Crush	for the Internet Recycle Machine	Page 1/1	
D/W	Required functions and constraints		Req. met?
D	Geometry Height must be comparable to standard cabinent height (99 cm) for US.[1]		110 cm
D	Height The input port should be at average Korean woman shoulder height (121 cm)[2]		140 cm
W	Noise The machine should be quiet (< 40 dB)		not tested
D	Motion The machine should complete one can crushing within 5 sec for automatic operation		not tested
D	Volume Must reduce volume of aluminum can for storage (80% reduction in volume)		yes
W	Cost Private unit must be affordable (< $ 150 USD)		$145
D	Material Must be corrosion resistant		yes
D	Stress Must be able to withstand stress in excess of 4500 grams (100 lbs)		not tested
D	Safety Must not post danger to hand or limb		yes
W	Automation The machine should be automated requiring little human energy to crush can		yes
W	Maintenance Few moving parts to reduce repair (parts < 25)		yes

[1] Kraftmaid Cabinetry. http://www.kraftmaid.com/whykm/index.cfm?navigationid=13500

[2] Ministry of Education and Human Resources Development, Korea 1970-2004

Dynamic crush was charged with working across time zones and cultures to develop a global product that creates a closed loop economy utilizing the internet. Team Crush was able to complete the design process from initial concept generation until prototype generation. There were milestones throughout the project including design reviews and presentations culminating in a prototype exhibition.

The overall task of developing a global product was completed using a common platform with modifications for the two markets. The closed loop economy task was completed using the internet kit integrated into the project to connect the consumers with a website that rewards recycling.

The objectives of creating and presenting design reviews were successful. Dynamic crush was able to complete the reports and presentations utilizing face-to-face meetings and videoconferencing. While the American members were more comfortable speaking in English, effort was made to include speakers from all branches.

One of the future considerations for the proposed design is to implement tighter security measures so as to ensure that no ‘cheating the system’ takes place, or illegitimitally getting more rewards for not doing the corresponding amount of recycling. One of these methods consists of using a bar code scanner to scan in the bar codes of aluminum beverage containers. This scanner will ensure that the container is indeed aluminum, and that it has yet to be crushed (since a crushed can will not be able to be read by the bar code scanner). The bar code scanner will also prevent foreign objects being placed into the recycling system.

Lessons Learned

This project has allowed the team to learn and grow into better communicators and engineers. A key point was learning to stay realistic. In addition to the project requirements there are always constraints. Whether it is time, budget or resources these constraints must be kept in mind during design. Working and learning about different cultures was critical not only to the global design of the product but to create team understanding. The cultures are very different and if attention is not given during design, the final product could be offensive. What is acceptable in one culture might be insulting to another. Project management is critical to completing a large task with many members. Assigning tasks to specific members is important to avoid misunderstandings and duplicating work. Creating a set of rules and expectations would have helped facilitate the meetings. It is critical to have as many group members at the video conferences. The video conferences were the best to get up to date reports and ask any questions to the team members.

Future recommendations to mandate at least one team member from each site attend the video conference would help. The video meetings with only two sites were not as productive because there were questions that could not be answered. While the teams were selected to have different expertise, an electrical engineer on each team would have helped to integrate the internet kit. The lecture on the internet device should include step-by-step instructions for a simple example that walks you through connecting and programming. The Hello device is not user friendly and should be robust as to not burn or break from testing.

Communication was critical to completion of this project. Instant messaging through MSN messenger was the most common form the team chose. However, the video conferences were the best for resolving concerns with the design. Having a designated member to take meeting notes and writing a summary after the video conference helped to let everyone know what tasks were assigned. There were instances when a potential misunderstanding was overlooked at the video conference but the mistake was corrected when the summary was sent to the group.

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Appendix:

Appendix A: Matrix of Top Five Ideas

Product Concept	Description	Markets	Internet Application	Closed Loop
Foot Water Pump / Exercise Machine	Water in developing countries needs to be pumped from a well. The feet-gliders that pump the water can also be used as an exercise machine.	Developing nations in Africa. Developed nations in North America or Europe.	Allows national governments to monitor water consumption in developing nation. Allows individual to monitor exercise progress and health.	Aids developing nations in obtaining clean water and receiving accurate aid details from NGOs or local governments. Person exercising can monitor health progress.
Vehicle Camera	Camera or sensor mounted in a car or truck that that recognizes the condition of the driver by her eye movements, and alerts the driver to pull over and rest.	All countries that allow night traffic of automated vehicles.	Contact police department if driver is falling asleep. Lets user monitor their patterns of driving while tired.	Possible reuse in older vehicles
Multifunctional Light	A light that can be remotely activated so as to avoid coming home to a dark house; A light that serves as an emergency flash light, and as a deterrent to burglars.	Single individuals; Traveling business people / vacationers; Developing countries, where product can be used as a simple light source.	User can control the light from remote locations.	Less material waste since one light has many applications. Design for manufacturability by reducing assembly operations.
Closed Loop Container	A dynamic container that alerts garbage collecting companies to clean public garbage containers (garbage is either picked up too often or not enough).	Rural areas with low populations (in developed countries) where waste is not collected on an accurate basis.	Reduce wasted time/effort discharging half-filled containers, thus reducing waste into environment.	The internet connectivity allows garbage collecting company to optimize collection schedule, and aid in protecting the environment.
Aluminum Can Recycling Machine	The decline in aluminum can recycling promotes a desire to create a machine that is easy to use and that encourages can recycling.	Individual households in USA; communities (public and private) in major cities of South Korea	Use the internet to record the number of cans recycled by each individual.	Create online competition to encourage recycling cans, with possibility of winning a prize while emphasizing being a 'green' individual.

Appendix B: Market Size Estimations for US and Korea

Market Size Estimate:

1. Estimate the number of households in the top ten
2. Assume that half of households will want to participate
3. Multiply the number of households by 1 unit to get market size.

Equation 1: US Market size estimation.

$$8M \text{ households} \times \tfrac{1}{2} \text{ households will use} = 4M \text{ households}$$

$$4M \text{ households} \times 1 \frac{\text{personal unit}}{\text{household}} = 4M \text{ total recycle units}$$

Market Size Estimate:

1. Estimate the number of major housing buildings in Seoul.
2. Each housing building would have one unit inside for the tenants and one outside at the major intersection for pedestrians.
3. Multiply the estimate from the city total by the number of cities to get market size.

Top Seven Major Korean Cities

- Busan
- Daegun
- Daejeon
- Gwanju
- Incheon
- Seoul
- Ulisan

Equation 2: Korean Market size estimation.

$$3100\frac{\text{housing units}}{\text{major city}}\times 2\frac{\text{recycle units}}{\text{housing unit}} = 6200\frac{\text{recycle units}}{\text{major city}}$$

$$6200\frac{\text{recycle units}}{\text{major city}}\times 7\,\text{major cities} = 43400\ \text{total recycle units}$$

Appendix C: Marketing Analysis Data for South Korea and USA

Target	Seven major Cities in Korea
Market Size	43,400 communal units
Market Feature	The amount of can which is consumed in Korea in 2003 is 60 billion cans. Recycling rate of Aluminum can is 70% in Korea. But, Japan has 87% recycling rate, German and Holland has 78% recycling rate, Korea government want to raise their recycling rate because of reducing cost and saving power
Customer Requirements	Quiet, easy to use, simple, quick cycle time, easy to clean, appearance
Target	Top ten most populated US cities
Market Size	4 million personal units
Market Feature	Aluminum can recycling is declining within the past three years[C-1]. To motivate consumers to participate in closed loop economy, incentives are needed. Recycling should be easy to compel customers to use.
Customer Requirements	Quiet, small, affordable, easy to operate, easy to clean, easy to maintain.

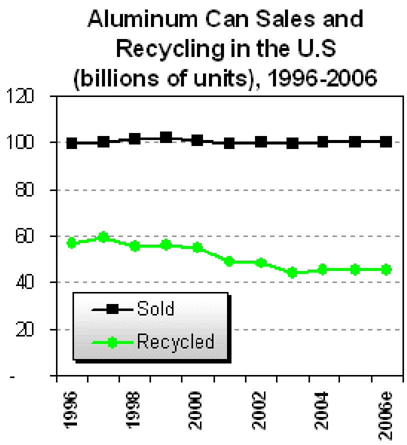


Figure C-1: Trend of number of cans in USA recycled against total sales of aluminum cans. Container Recycling Institute, Graphs: Aluminum Can Statistics. [Online] Available *http://www.container-recycling.org/alumrate/graphs.htm*, October 10, 2007

Appendix D: Patent Search

D-1: *Pat Num 5,507,22,2 Can Crusher, Oliver M. Reavy.*
This patent makes use of crushing a can by placing the device on the ground and securing it with the user's foot. Once the can is in place, the user simply pushes down on the lever to crush the can.

D-2: *Pat Num 5,456,166 Can Crusher with Safe Entry and Discharge Chutes, David C. Belongia & Sally K. Cashin*
This patent makes use of an automated crushing mechanism that is controlled by gears. The user loads a bunch of cans into the machine, and then presses a button that activates the crushing mechanism. Once a can is crushed, it falls out into a bin that is placed directly under

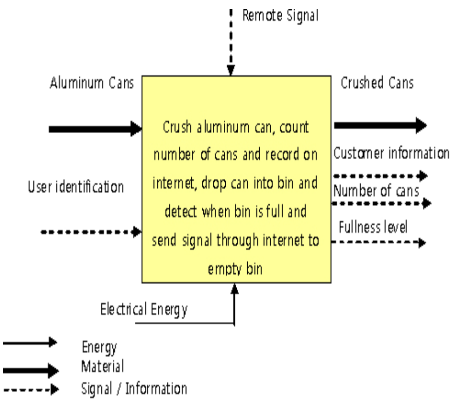
.

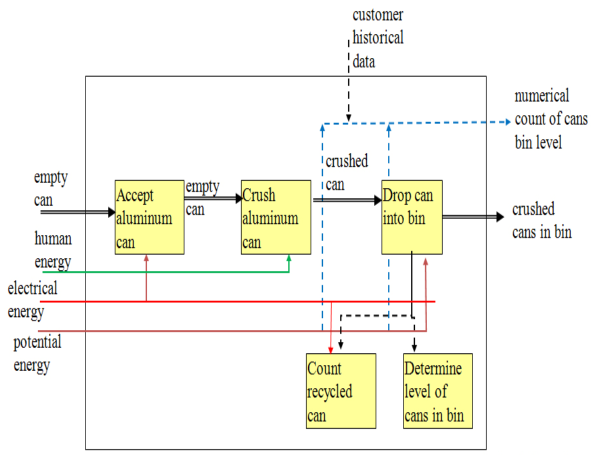
D-.3: *Patent Num 4,292,891 Aluminum Can Crusher, James D Shelley*
This patent makes use of a hand operated crushing mechanism, but differs in the way that the can is crushed. Here, the can is crushed by bringing the two ends of the container together such that there is almost a common point between the circular ends. Once the user has finished crushing the can, she simply removes the can by hand. This machine operates by placing on a flat surface, and then crushing the can.

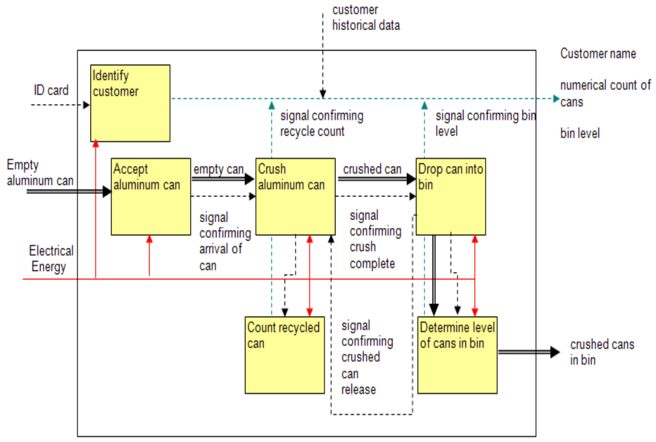
D-4: *Patent Num 5,211,109 Beverage Can Crusher, Jerome A. Determan.*
This patent makes use of automated rollers within a public can-recycling machine. As shown in the figures, the can is crushed along its length. The user drops the can into a chute, which in turn feeds into the set of rollers. Once the can is crushed, it falls into a recycling bin.

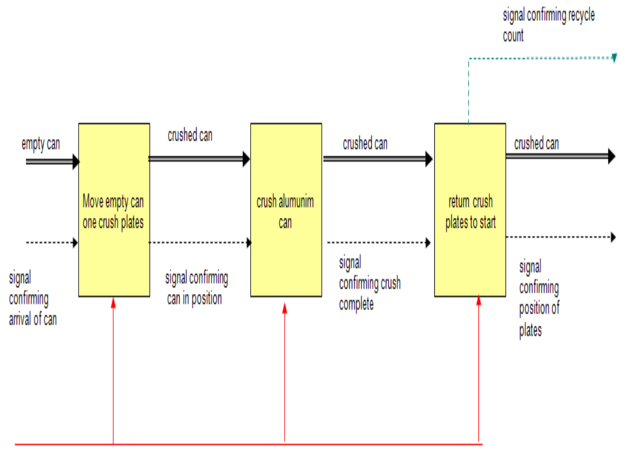
D-5: *Patent Num 5,121,685 Can Crusher, John Turner*
The patent pictures above describe an automated can recycling system that is designed for large scale applications. Once the can is in place for crushing, a piston comes in and pushes into the center of the can, thereby creating a dent about which the can will collapse in. Next, the plunger pushes into the can so as to bring the faces of the can together in a coplanar relationship. Once the can is crushed, it falls into a recycling bin through a small slot.

Appendix E: Functional analysis

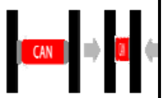
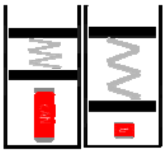
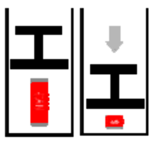
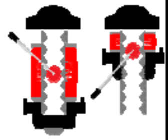


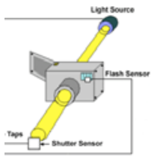
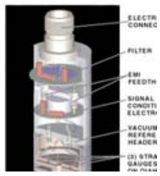
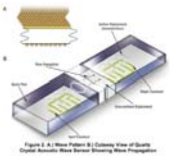


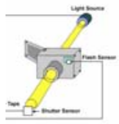
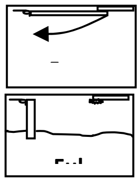


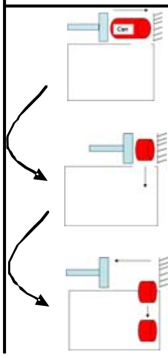
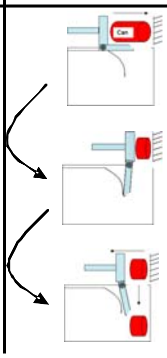
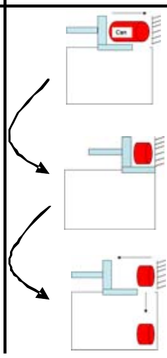
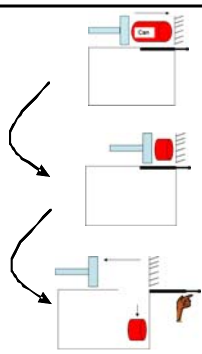


Appendix F: Sub Function with working principles.

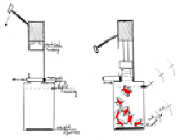
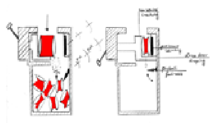
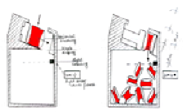
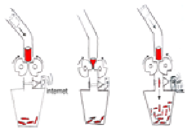
Sub-Function I	Working Principles #1	Working Principles #2	Working Principles #3	Working Principles #4	Working Principles #5
Crush	Crush horizontally	Crush vertically with spring	Crush vertically with weight	Crush vertically with lever	Crush with rotary wheel
					

Sub-Function II	Working Principles #1	Working Principles #2	Working Principles #3	Working Principles #4	Working Principles #5
Counting	Light Sensor	Weight Sensor	Pressure Sensor	Sound Sensor	Wave Sensor
					

Sub-Function III	Working Principles #1	Working Principles #2	Working Principles #3	Working Principles #4
Fullness Sensing	Light Sensor	Weight Sensor	Pinball	Manual Counting
				

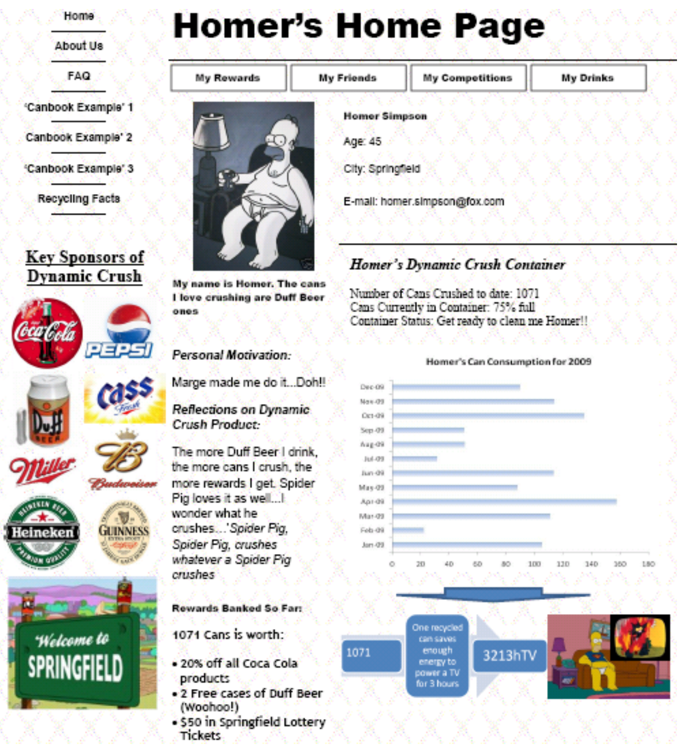
Sub-Function IV	Working Principles #1	Working Principles #2	Working Principles #3	Working Principles #4
Dropping Crushed Can	Simple Opening	Spring / Track Cover	Trap Door	Manual opening
				

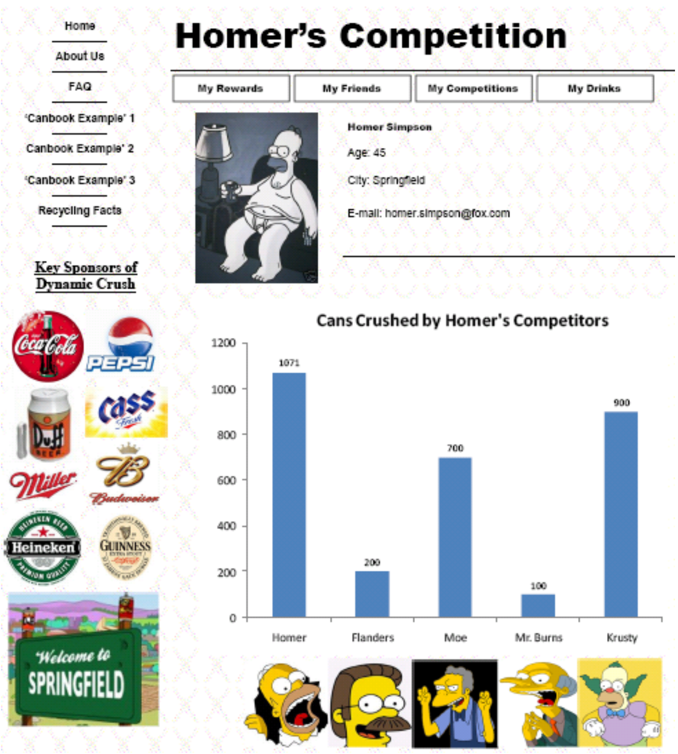
Appendix G: Design Alternative Matrix

Criterion			Grade			
			A 	B 	C 	D 
Item	Details	Weight				
function	sound of crushing	2	3	3	2	2
function	Time to crush	3	3	5	7	10
realize	small space	2	5	5	4	4
simple	number of parts	1	1	3	3	2
manuf.	simple machining	1	6	7	4	4
ass'y	easy assembly	2	6	7	5	3
usage	simple user interface	3	3	4	7	9
clean	easy cleaning	2	6	5	5	5
robust	low maintenance cost	2	3	4	6	2
Sum	total of (weight x grade)		71	85	93	95
	priority		4	3	2	1

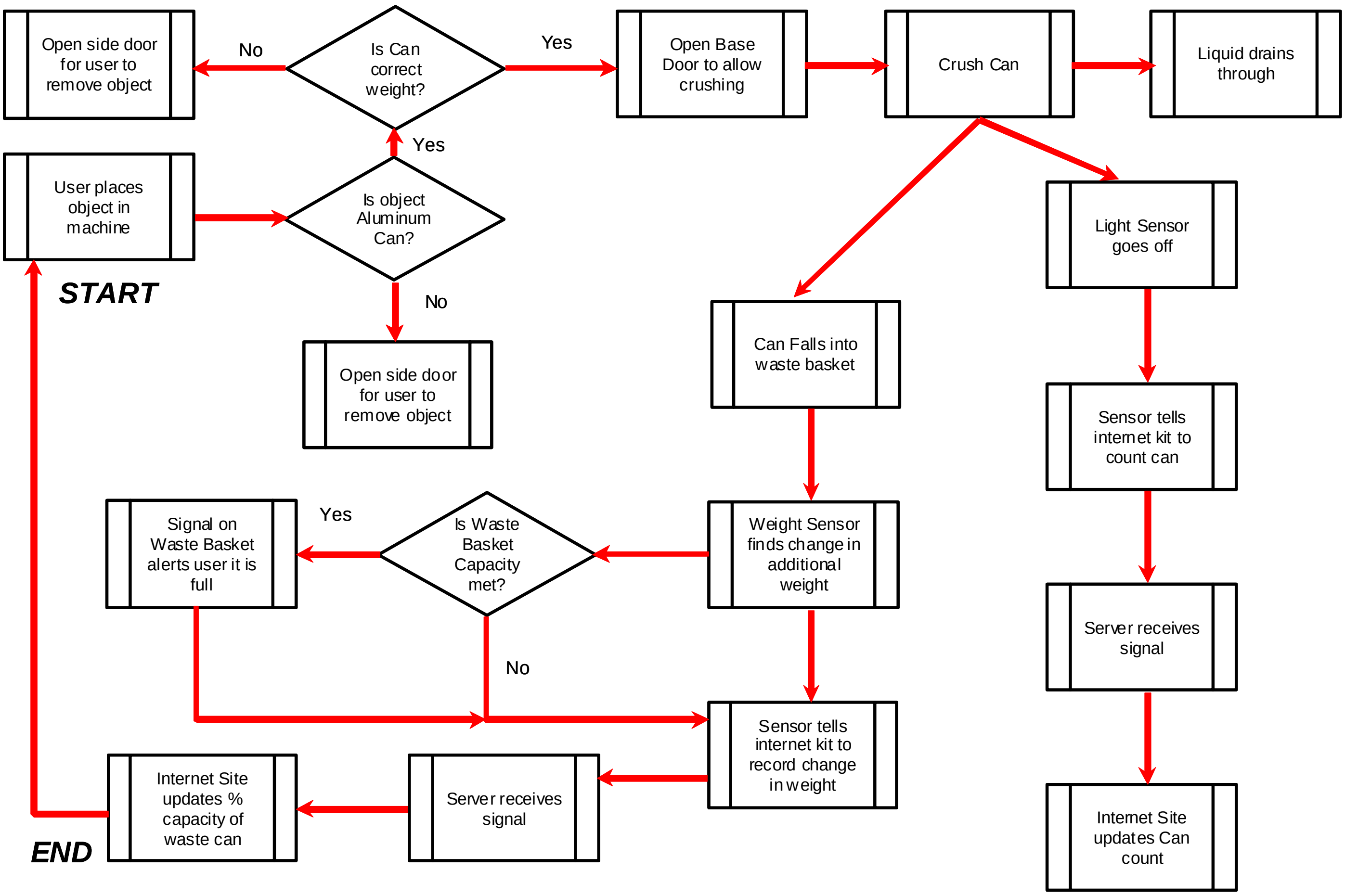
tical crush, manual dropping, light sensor, weight sensor
izontal crush, trap door dropping, pressure sensor, pinball sensor
gled manual crushing, simple dropping, light sensor, light sensor
gled electric crushing, simple dropping, light sensor, light sensor

Appendix H: Canbook Screenshots (online interactive interface)

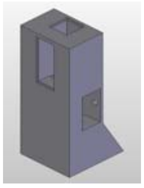
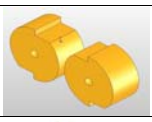
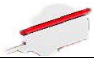
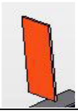
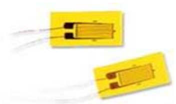
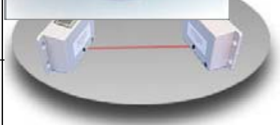
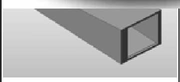
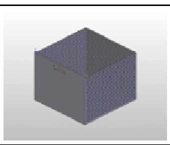
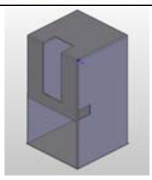




Appendix I: Flow Chart of Customer Interface (Interactions between Customer and Recycling Bin)



Appendix J: BOM for Dynamic Crush Proposed Final Design

Item NO	Image	Sub-Assembly	Name	Notes	Quantity	Material	Manufacturing
1		Automatic Crushing	Core	Height 505 Top 120 / Bottom 160 Width 190	1	Stainless Steel	Machined
2			Rotary Wheels	D132 x 70	2	Stainless Steel	Machined
3			Bearings	For support of shaft	2	Stainless Steel	Machined
4			Shaft	D20 x 200	2	Stainless Steel	Machined
5			.5 hP electric motor	2 for rotary wheels 1 for door operation	3	Composite	Chicago Electric Power Tools
6			Horizontal Plate	120 x 80 x t5	2	Stainless Steel	Machined
7			Removal Door	210 x 80 x t5	1	Stainless Steel	Machined
8			Strain Gauge	Weight Check	3	Nickle	Omega
9			Wave Sensor	Material Check	1		Pacific Sensor
10			Reflective Barrier Sensor	Send signal to internet kit for Counting	1	Infrared	Welotec
11			Liquid Storage	120 x 100 x 305	1	Stainless Steel	Machined
12			HelloDevice 1100	Internet kit	1	Sena Technologies	
13		Drawer Assembly	Mesh Drawer	500 x 490 x 130	1	HDPE	Blow Mold
14			Digital Weight Scale	Send signal to internet kit for Fullness	1		
15			Drawer track	For draw open / close	2	Stainless Steel	
16			Shell Housing	Need Dimensions	1	HDPE	Blow Mold

Appendix K: Platforms and Estimated Prototype BOM

American Platform

Automatic Crushing	Core
	Horizontal Plate
	Removal Door
Removable Liquid Storage Tray	
Drawer Assembly	Mesh Drawer
	Drawer track
Plastic Shell	

Shared Platform

Rotary Wheels
Bearings
Shaft
.5 hP electric motor
Strain Gauge
Wave Sensor
Reflective Barrier Sensor
HelloDevice 1100
Digital Weight Scale

Korean Platform

Automatic Crushing	RFDA card reader
	Visual Display
	Removal Door
Liquid Storage	Mesh grid
	Connection to sewer
Recycling Bin	Lockable Door
	Rolling bin
Large Metal Shell	

Estimated Prototype BOM

ManualCan Crusher	Purchased in USA
Wave Sensor	Purchased in USA
Strain Gauge	Purchased in USA
Wiring and electronics for 2 sensors	Purchased in USA
Recycling Bin	Purchased in Korea
Reflective Barrier Sensor	Purchased in Korea
Hello Device	Donated in Korea
Digital Weight Scale	Purchased in Korea
Wiring and electronics for 2 sensors	Purchased in Korea
Machine Housing	Purchased in Germany

Appendix L: Motor Assumptions, Calculations & Manufacturers

The team created a set of assumptions in determining the motor requirements to crush an aluminum can. Given that cans crushed by individuals consist of pressing the can to the floor via stamping on it (such that the can bends to failure and then compresses), the team used the average weight of an American woman[1] (140lb, or 622.75 N) as the input force to crush a can. The time to crush the can consisted of 0.25 seconds, and the distance to compress the can consisted of 80% of the standard 12.2 cm tall can (9.76 cm). Using this information, the equivalent power to crush a can is 243.15 Watts, or 0.33hp. Using a factor of safety of 1.5, the approximate power rating of each motor to rotate the crushing mechanism is 0.5 hp.

1. http://www.websterhabitat.org/recycle/index.php

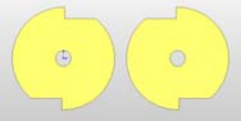
Manufacturer Information (website)

Crompton & Greaves Motors (0.5 hp power output)

http://www.cglonline.com/products/international/motorandpump_p3.htm

Fujian Julong Electric Co. (0.5 hp power output) http://glong-motor.en.alibaba.com/offerlist.html

Appendix M: Rotary Wheel Assumptions & Calculations



Using a base diameter of an aluminum can to be 6.6 cm and respective height to be 12.2 cm, the team created the necessary dimensions to completely crush a can. With a target goal to crush the can to 80% of its size, the team decided that the gap between the rotors should be 1.5 cm (thus, reducing the can base length by 77%). The team decided that the radius of each rotor should be 6.6 cm, equivalent to the diameter of a can. Next, team decided that in order to 'catch' the can between the rotors, the initial break into each rotor should be 1.5 cm: this ensured that the arc length coming into contact with the sides of the can during crushing (with one half turn of each rotor) was at least equivalent to the height of the can, thereby crushing it completely. Through an angle of 2.49 radians, the actual arc length coming in contact with the can is 16.4 mm (arc length = radius × angle). The thickness of each rotor was chosen as 7.0 cm (just greater than the diameter of the can) to ensure that the entire can when through the crushing process.

Appendix N: Calculations for Bin Size & Geometry

http://www.websterhabitat.org/recycle/index.php

1022 cans/yr = ~20 cans /week

http://www.cancentral.com/pdf/CMIBevCanData1970-2005.pdf

2005 = 99.157 billion cans

http://factfinder.census.gov/servlet/NPTable?_bm=y&-geo_id=01000US&-qr_name=ACS_2005_EST_G00_NP01&-ds_name=&-redoLog=false

2005 = 288.4 million people

2.6 average household

Calculate:

99.157billion cans/288.4 million people = 343.8 cans/person/year

343.8 cans/year = 6.61 cans/ week

Average household can usage:

6.61 cans/person/week * 2.6 person/household = 17.19 cans/house/week

Appendix O: Sensor Research

Material Detection – Wavelength sensor
Working principle: A light beam is sent to the object and three phenomena occur: reflection, absorption and transmission. The parameters and conditions vary according to the object. The results of the light beam vary according to color, material, thickness and color. These properties allow the wavelength sensor to detect if the object is aluminum. Can Fullness Detection – strain gauges Working principle: Strain gauges are placed on a surface and measure the defection of the surface from an object. For the fullness sensing, experiments will determine the strain gauge values for a full can, empty can and a 1 oz. full can. The strain gauge value will be programmed to reject the can if the value is greater than 1 oz.

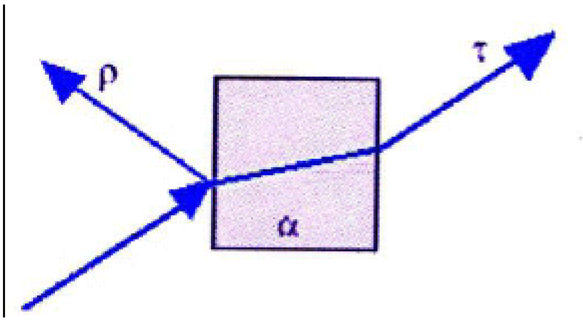


Figure O-1: Wavelength sensor working principles.

Counting Recycled Cans – IR refection barrier sensor
Working principle: A transmitter and receiver are separate units. The infrared light emitting diode sends a signal to the receiver with a fixed frequency modulated light. This is light is reflected off the receiver and sent back to the transmitter. When an object breaks the light beam a signal is sent through the sensor to count a broken transmission.

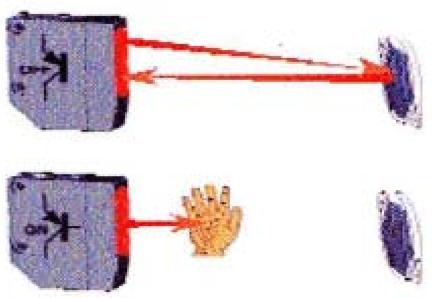


Figure O-2: IR sensor working principles.

Measuring Recycle Bin Level – digital weight scale
Working principle: Weight is placed on the scale and a digital signal is sent recording the weight. The scale will be placed under the mesh bin and "zeroed" to account for the weight of the bin. Experimentation to determine empty, 50% (15 cans), 75% (~22 cans), 80% (23 cans), 90% (27 cans), 95% (28 cans) and 100% (30 cans) yields thresholds for display to the customer. A simple program to convert the digital signal to a percentage will be displayed on the customer account.

Appendix P: Prototype Design Parts

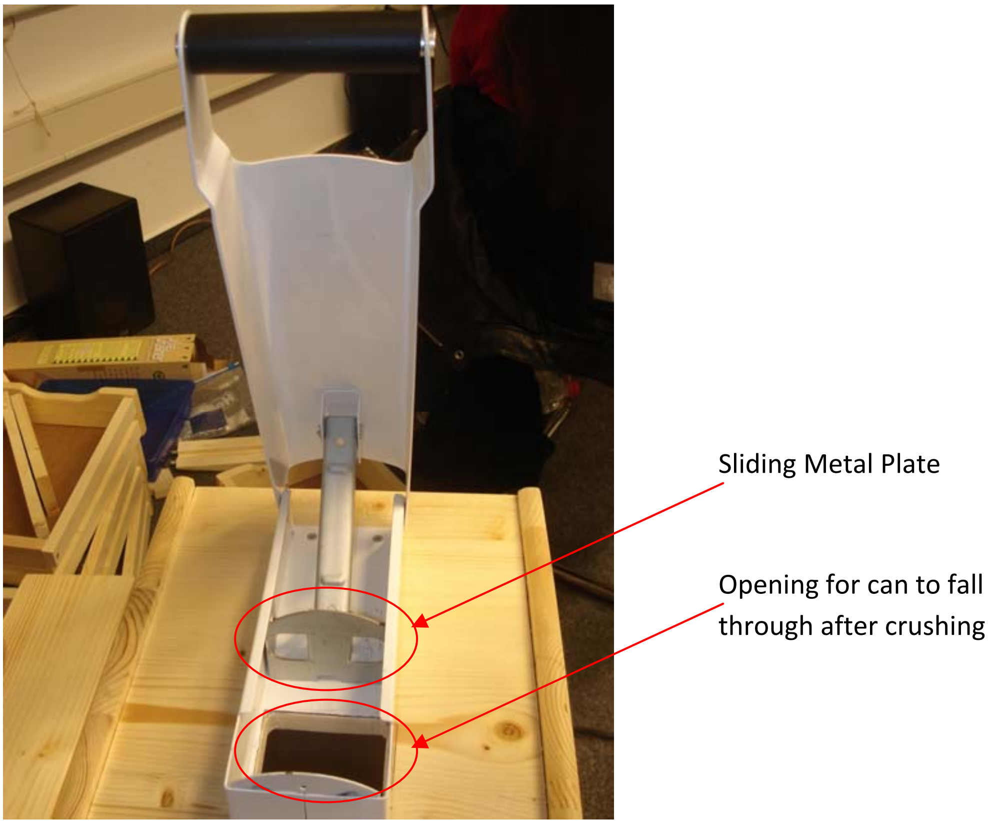


Figure 1. Image of customized hand-crank can crushing system

Figure 2: Images of supporting box structure to support all components.

Figure 3: Image of can collection tray (left) and liquid collection tray (right)

Figure 4: Image of weight scale to measure weight of empty can

Figure 5: Image of ultrasonic wavelength sensor to count cans

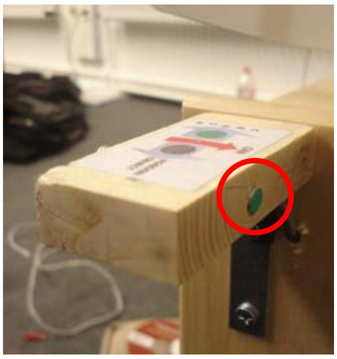


Figure 6: Image of inductive proximity sensor to detect aluminum can

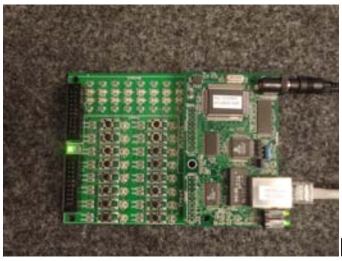
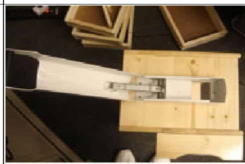
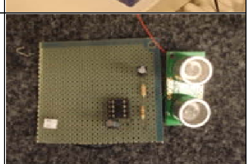
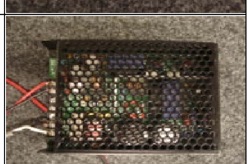
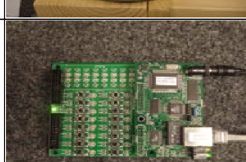


Figure 7: Image of internet connectivity kit

Appendix Q: BOM Prototype

Item NO	Image	Sub-Assembly	Name	Notes	Quantity	Material	Manufacturing
1		Manual Crushing	Manual Can Crusher with Machined Exit Hole	**Main Unit:**Length: 16.8" Width: 4.3" Height: 3.0"	1	Steel	Basic Industries Inc (base unit); Steel cutting saw to machine out exit hole
2		System Housing	Overall Wood Support		1	1" thick Plywood	Wood Cutting, drilling
3			Brackets	Support for the wooden box structure		Stainless Steel	Purchased from Home Depot
4			Screws	Support for the wooden box structure		Stainless Steel	Purchased from Home Depot
6		Drawer Assembly	Mesh Storage Bin	To collect crushed cans	1	Plastic (Get material)	Purchased from BausHaus (injection molded)
7			Liquid Storage Tray	To collect excess liquid from cans after crushing	1	Plastic (Get material)	Purchased from BausHaus (injection molded)
8			Ultrasonic Wavelength Sensor	Storage Unit 'Fullness' Check	1	Ultrasonic Waves	SensorTech and Devantech Products
9			Power Unit	Provide Power to Ultrasonic Wave Sensors	1		
10		Counting Cans	Ultrasonic Wavelength Sensor	Count number of cans crushed	1	Ultrasonic Waves	SensorTech and Devantech Products
12		Determining Can Material	Inductive Proximity Sensor	To determine if can is made of aluminum or of steel	1	Electromagnetic Field	Siemens and Turck Products
13		Determining Can Weight	Digital Kitchen Scale	To determine if can to be crushed is empty	1		BauHaus
15		Connecting to Internet	HelloDevice 1100	Internet kit	1	Sena Technologies	

obfile)ffile)

Appendix R: Cost Structure & Pricing, Primary Market

Total Fixed Cost/yr: $8,630,000

Total Variable Cost/yr: $386,102,723.2

Total Cost/yr: $394,732,723.2

Number of Units produced/yr: 4,000,000

Unit Cost: $98.68

Mark up: 50%

Expected Price for Primary Market: $148.02

Assumptions:

Fixed costs consisted of the rental use of a 10000 m^2 plot of land, the necessary labor costs (manual to purchasing to internet support), and the costs of owning and maintaining assembly stations to produce each unit. These costs did not include any such items such as investments in different manufacturing processes (i.e. stamping, bending, etc.) as our goal is to serve as an 'assembly' business of the product. Variable costs associated with our product consisted of taking into consideration the costs of raw materials, associated labor costs in outsourcing the machining of these materials, and the costs of ready made items (such as sensors and motors) into creating the product.

Prices for raw materials were taken based on buying in bulk and taking advantages of economies of scale. Since the core components of the product intended for the secondary market are the same as those for the primary market, it was assumed that the prices for these components in each market would be significantly different (since the amount required in the primary market was 100 fold than that of the secondary market).

The sizes of the different components based on the final design drawings for the products intended for each market.

Appendix R: Fixed Cost Structure, Primary Market

Land costs	
Area of Land (m^2)	10000
Cost per m^2 (Rental cost/yr) ($)	100
Total Cost of land ($)	**1,000,000**
Labor	
Assembly Labor	
Number of shifts per day	3
Hours per shift	8
Hours worked per year	2000
Number of Assembly Linesman / shift	66
Total Number of Assembly Linesman reqd	200
Cost per Labor unit ($/hr)	15
Total Assembly Labor cost/yr ($)	6,000,000
Line Manager Labor	
Number of shifts per day	3
Hours per shift	8
Hours worked per year	2000
Number of Line Managers/shift	1
Total Line Manager reqd	3
Cost per Line Mngr /hr	25
Total Line Manager cost/yr ($)	150,000
Purchasing Manager Labor	
Number of shifts per day	1
Hours per shift	8
Hours worked per year	2000
Number of Purchasing Manager/ shift	3
Total Purchasing Mngr	3
Cost per Purchasing Manager ($/hr)	30
Total Purchasing Manager cost/yr ($)	180,000
PR / Marketing Manager Labor	
Number of shifts per day	1
Hours per shift	8
Hours worked per year	2000
Number of Purchasing Manager/ shift	3
Total PR / Markting Manager	3
Cost per PR/Marketing Manager ($/hr)	50
Total PR / Markting Manager cost/yr ($)	300,000
IT / Software Manager Labor	
Number of shifts per day	1
Hours per shift	8
Hours worked per year	2000
Number of IT/Software Manager shift	10
Total IT/Software Manager	10
Cost per IT/Software Manager ($/hr)	45
Total IT/Software Manager cost/yr ($)	900,000
Total Cost/yr Labor ($)	**7,530,000**
Assembly Stations	
# of stations required	67
Cost/stn per year ($)	1500
Total Cost per year ($)	**100,000**
Grand Total Fixed Cost/yr ($)	**8,630,000**

Appendix R: Variable Cost Structure, Primary Market

Variable Costs	
Cost of Stainless steel (cost/unit area) ($/mm^2)	0.0000238
Area of Inner Core (mm^2)	414300
Stainless Steel inner core (cost/unit)	9.86034
Total Cost/yr of Inner Core ($)	39,441,360
Cost of HDPE Plastic (cost/unit area) ($/mm^2)	0.000001266
Area of Outter Core (mm^2)	2828800
HDPE outer core (cost/unit)	3.5812608
Total Cost/yr of Outer Core ($)	14,325,043
Surface Area of Storage Bin (mm^2)	502,400
Stainless Steel Storage Bin Cost/unit ($)	11.95712
Number of Bins per Unit	1
Total Cost/yr of bins ($)	47,828,480
Surface Area of Liquid Storage Unit (mm^2)	158200
Numer of Liquid Storage Unit per system	1
Liquid storage unit cost/ system ($)	3.76516
Total Cost/yr of Storage Unit ($)	15,060,640
Surface Area of each access door/plate (mm^2)	12000
Number of Doors/ system	3
Cost of a single door ($)	0.2856
Total Cost/yr of Access Doors ($)	3,427,200
Cost of bearings ($/bearing)	0.25
Number of Bearings per unit	2
Total cost of Bearings/yr ($)	2,000,000
Cost of Extruded Stainless Steel ($/mm)	0.0025
Length of rod (mm)	200
Number of rods per unit	2
Cost of one rod ($)	0.5
Total cost of rods/yr ($)	4,000,000
Cost of 0.5 hp DC motor	20
Number of Motors/unit	2
Total Cost motors/year ($)	160,000,000
Sensors + Internet Kit	
Cost of Strain Gage (per unit) ($)	11.5
Cost of Proximity Sensor (per unit) ($)	6.175
Cost of Ultrasonic Sensor (per unit) ($)	3.33
Cost of Weight Scale (per unit) ($)	3
Cost of Internet Kit (per unit) ($)	1
Total Cost/yr of sensors ($)	100,020,000
Total Variable Cost ($)	386,102,723.20

Appendix R: Cost Structure & Pricing, Secondary Market

Total Fixed Cost/yr: $2,239,000

Total Variable Cost/yr: $73,120,678

Total Cost/yr: $75,359,678

Number of Units produced/yr: 45,000

Unit Cost: $1,674.66

Mark up: 50%

Expected Price for Primary Market: $2,511.82

Assumptions:

Fixed costs consisted of the rental use of a 10000 m^2 plot of land, the necessary labor costs (manual to purchasing to internet support), and the costs of owning and maintaining assembly stations to produce each unit. These costs did not include any such items such as investments in different manufacturing processes (i.e. stamping, bending, etc.) as our goal is to serve as an 'assembly' business of the product. Variable costs associated with our product consisted of taking into consideration the costs of raw materials, associated labor costs in outsourcing the machining of these materials, and the costs of ready made items (such as sensors and motors) into creating the product.

Prices for raw materials were taken based on buying in bulk and taking advantages of economies of scale. Since the core components of the product intended for the secondary market are the same as those for the primary market, it was assumed that the prices for these components in each market would be significantly different (since the amount required in the primary market was 100 fold than that of the secondary market).

The sizes of the different components based on the final design drawings for the products intended for each market.

Appendix R: Fixed Cost Structure, Secondary Market

Land costs	
Area of Land (m^2)	10000
Cost per m^2 (Rental cost/yr) ($)	100
Total Cost of land ($)	**1,000,000**
Labor	
Assembly Labor	
Number of shifts per day	3
Hours per shift	8
Hours worked per year	2000
Number of Assembly Linesman / shift	10
Total Number of Assembly Linesman reqd	30
Cost per Labor unit ($/hr)	9
Total Assembly Labor cost/yr ($)	540,000
Line Manager Labor	
Number of shifts per day	3
Hours per shift	8
Hours worked per year	2000
Number of Line Managers/shift	1
Total Line Manager reqd	3
Cost per Line Mngr /hr	15
Total Line Manager cost/yr ($)	90,000
Purchasing Manager Labor	
Number of shifts per day	1
Hours per shift	8
Hours worked per year	2000
Number of Purchasing Manager/ shift	1
Total Purchasing Mngr	1
Cost per Purchasing Manager ($/hr)	18
Total Purchasing Manager cost/yr ($)	36,000
PR / Marketing Manager Labor	
Number of shifts per day	1
Hours per shift	8
Hours worked per year	2000
Number of Purchasing Manager/ shift	2
Total PR / Markting Manager	2
Cost per PR/Marketing Manager ($/hr)	27
Total PR / Markting Manager cost/yr ($)	108,000
IT / Software Manager Labor	
Number of shifts per day	1
Hours per shift	8
Hours worked per year	2000
Number of IT/Software Manager shift	5
Total IT/Software Manager	5
Cost per IT/Software Manager ($/hr)	27
Total IT/Software Manager cost/yr ($)	450,000
Total Cost/yr Labor ($)	**1,224,000**
Assembly Stations	
# of stations required	10
Cost/stn per year ($)	1500
Total Cost per year ($)	**15,000**
Grand Total Fixed Cost/yr ($)	**2,239,000**

Appendix R: Variable Cost Structure, Secondary Market

Variable Costs	
Cost of Stainless steel (cost/unit area) ($/$mm^2$)	0.0001193
Area of Inner Core (mm^2)	414300
Stainless Steel inner core (cost/unit)	49.42599
Total Cost/yr of Inner Core ($)	2,224,170
Cost of Stainless steel (cost/unit area) ($/$mm^2$)	0.0001193
Area of Outter Core (mm^2)	6836800
HDPE outer core (cost/unit)	815.63024
Total Cost/yr of Outer Core ($)	36,703,361
Surface Area of Storage Bin (mm^2)	3660000
Stainless Steel Storage Bin Cost/unit ($)	436.638
Number of Bins per Unit	1
Total Cost/yr of bins ($)	19,648,710
Surface Area of Liquid Storage Unit (mm^2)	158200
Numer of Liquid Storage Unit per system	1
Liquid storage unit cost/ system ($)	18.87326
Total Cost/yr of Storage Unit ($)	849,297
Surface Area of each access door/plate (mm^2)	12000
Number of Doors/ system	3
Cost of a single door ($)	1.4316
Total Cost/yr of Access Doors ($)	193,266
Cost of bearings ($/bearing)	2.5
Number of Bearings per unit	2
Total cost of Bearings/yr ($)	225,000
Cost of Extruded Stainless Steel ($/mm)	0.025
Length of rod (mm)	200
Number of rods per unit	2
Cost of one rod ($)	5
Total cost of rods/yr ($)	450,000
Cost of 0.5 hp DC motor	80
Number of Motors/unit	2
Total Cost motors/year ($)	7,200,000
Sensors + Internet Kit	
Cost of Strain Gage (per unit) ($)	58
Cost of Proximity Sensor (per unit) ($)	31
Cost of Ultrasonic Sensor (per unit) ($)	17
Cost of Weight Scale (per unit) ($)	15
Cost of Internet Kit (per unit) ($)	5
Total Cost/yr of sensors ($)	5,626,875
Total Variable Cost ($)	73,120,678.05