ES202X Innovation Through Making

Final Project Design Report

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Team 2 - SAFE

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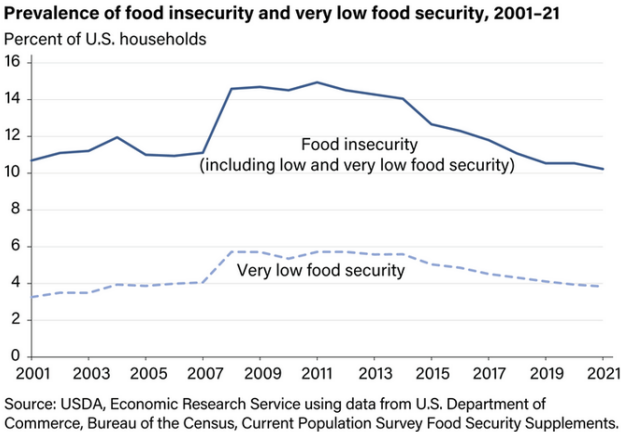
Testing	Soven, James	Cristian
Strengths	Soven	James
Compromises	Cristian	Michael
Economics	Michael	Cristian
Conclusion	Michael	Cristan, James
Recommendations	Cristian, Michael	James
Future Work	Cristian, James	Soven

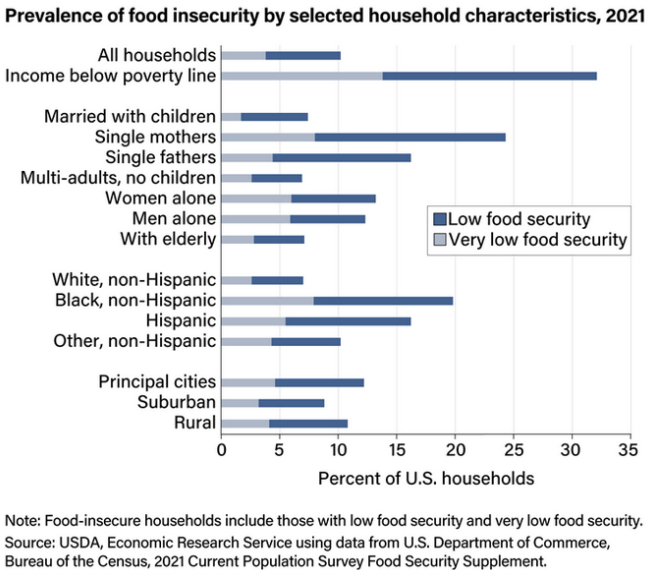
Intro and Empathy

Abstract

The objective of this report is to give the reader an insight into the process of designing and prototyping a device that allows for efficient storage of food. A lot of people currently facing food insecurity have issues accessing food due to the short time frames that food banks are open.

The issue of food insecurity is currently affecting 3.8% of households in the United States [1]. Although this percentage may appear small, it translates to approximately 5.1 million households, highlighting the significant impact of this problem [1]. Oftentimes, people have trouble making it during operating hours to their nearest food bank, causing them to live meal-to-meal.





To address this problem, we created a Secure Access Food Enclosure also known as the “SAFE.” It functions similar to an Amazon Locker, the people from the food banks are able to place food in the SAFE which is designed with an anti-robbery system. It allows for people, who are not able to come in during the short time food banks are open, to pick up the food at their earliest convenience. This helps households with working parents to still pick up food even at times outside of the food banks operating time.

Project Goals

While designing and prototyping this product we kept in mind the requirements for the technical parts. We thought about what would be needed to create the SAFE and at the same time how we could reduce the cost so that it would be affordable to make and sell. We went through different iterations of the product and faced failures at different points. When we tried to create the handle through vacuum forming it ended up being flimsy and unusable. We also realized that having the safe temperature controlled was too difficult to implement because it required too many input output pins and there was not enough power. While considering the technical elements we were also viewing it from the point of view of a user. We talked to different food banks to learn how we could create a product that would alleviate the stress and challenges faced by some of their volunteers.

Overall, the prototyping and making of the SAFE enables food banks to be more accessible and reliable. It reduces food insecurity by making the food available at times where the food bank is not operating. The SAFE provides a secure and dependable way for people to access food whenever they need it most.

Define

Problem Statement

From work to personal chores, people seem busier than ever in their day-to-day lives. Ensuring that people are sufficiently energized is vital to tackling the global food security problem. People searching for low cost or free food solutions typically come from low-income communities. Finding a means of transportation to retrieve their food at a time that aligns with the operating hours of a food bank can prove to be difficult. Furthermore, others who wish to receive food and supplies without face-to-face interaction due to fear of diseases such as COVID-19 may also have trouble. Therefore, some sort of solution has been deemed necessary to help tackle these food-related issues.

Needs Statement

Currently, there are no affordable food lockers tailored towards food bank or soup kitchen use on the market. Food lockers have been made for office/warehouse use but have a very expensive price tag and do not have multi-compartments for foods with

different temperatures. Some challenges food banks face that we would like to address are the issues of not being open 24/7 so the access to food is minimized. From interviews, food banks suffer from the issue that they are typically open for one day only, whereas they have hungry people every day of the week. The solution that our team has devised is to create an insulated, multi-compartment food locker that allows users to retrieve the nutrients they need daily on their own time and without the need of food bank workers/volunteers being present. This device would look and operate very similar to the automated Mail Locker system seen on campus at the bottom of the Campus Center. To uphold safety standards, these lockers should be easy to clean by the Food Banks.

The team has defined a few baseline requirements for the device. First, the device has to be user-friendly, being easy to access and use, and with a simplified food retrieval process. Second, the device must be big enough to house sufficient food, however, not too big of a size where it may obstruct hallways or access points that it is placed near. Finally, the device should be fully autonomous without the need of human monitoring. In the case that it does require attention, the components of the device should be easily accessed and replaced.

To create an easy-to-understand device, a response system must be put in place. A Liquid Crystal Display, or LCD screen displays text to users during the password input process. The buzzer responds to successful and unsuccessful inputs on the device. The device will need to detect possible robbery attempts and create a loud noise to help deter the culprits.

To summarize, there is a major need to access food safely and when needed, something that is easy to use, responds to user actions, and can prevent others from stealing food/supplies.

Design Goals and System Description

This device prototype has been structured to allow for users to receive their food and supplies on their own schedule. An LCD screen prompts users to input their personal password into the keypad. If the attempt is successful, the screen will notify the users and the SAFE’s door will unlock. Once users retrieve their food, they return the door to its original place and press a button to lock the device. If the attempt is unsuccessful, the device will buzz and tell users to try again. If a user forcefully unlocks the door, the device will make a loud noise and the screen tells the user to close the door.

Design Specs and Constraints

The SAFE device uses a 16x2 LCD screen to interact with users. A 4x4 matrix keypad is used for users to enter their PIN number. The 5V buzzer responds to input attempts and robberies. In addition an HC-SR04 Ultrasonic Sensor is used to detect robbers. The SG90 9g Micro Servo locks and unlocks the SAFE door to protect the inside contents. Finally, all components are connected using multiple jumper wires and interact with an Arduino Uno microcontroller board. Given the number of I/O pins and supplied voltage, we were not able to incorporate the LED system or temperature-controlled compartments as hoped. The next iteration of the device will have to address these constraints.

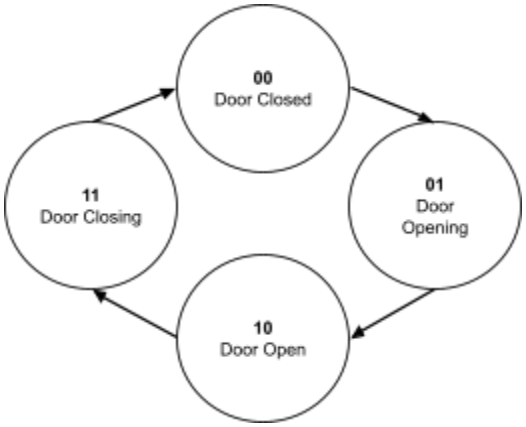
Ideation

Solution Development

Our team took great inspiration from the Design Thinking framework used in class during activities like the Backpack Design challenge. We first began by defining our goals and wishes for the device. The main goal was to help relieve food insecurities and make it easy for people to get the food they need when they want. A major want that we had was making the device either easy to build or affordable to buy for food banks or soup kitchens.

We then came up with a solution and decided it was time to pitch this to a potential customer for feedback. As we pitched it to the food banks, such as the Carty Cupboard Food Pantry [2] pictured below, we were able to ask specific questions that would allow us to evaluate our current prototype. With feedback we were able to decide on having three compartments to accommodate different items (compartments: hot, cold and room temperature). Our first design had only one compartment and did not take into consideration perishable and non-perishables. With feedback we were able to make our design more realistic and sensible.

We initially considered having an LCD screen which would display the temperature but due to constraints on power, size and price we decided not to go through with it. Another part of our design that did not happen was a LED lighting system. That was due to it needing a 12-volt power system which would require multiple power supplies.



The device operates according to the Finite State Machine (FSM) diagram above. In total, there are 4 device states. The initial position is when the door is closed. If a user inputs a wrong PIN, the closed state remains. If a user inputs a correct PIN, the next state is when the door opens. At this state, the buzzer makes a “happy” sound and the LCD screen confirms the PIN. Furthermore, the servo motor moves into the unlocked position, allowing users to open the door. At the next state, the user opens the door and they can grab whatever contents are inside. After retrieving their food and supplies, the user advances the device to the next state by returning the door to its closed position and pressing a button to lock the door again. At the next state, the door

completely closes and the servo returns to the locking position. Once the door is completely locked, the device returns to the original closed state and the process repeats again.

The Anti-Robbery system also depends on this FSM. An Ultrasonic sensor is placed inside of the enclosure and is facing the door, continuously reading the distance. The only states that the distance should be far from the sensor is during the Door Opening (01), Door Open (10), and Door Closing (11). At the Door Closed state (00), the distance should remain very small. When a robber forcefully opens the door at this state, the Ultrasonic sensor will detect an increase in the distance read, setting off the buzzer system and an LCD message. This alarm will only turn off once the door has been closed again.

Final Design

The final design that our team chose for this prototype was a laser-cut rectangular box, similar to other Arduino locker projects seen on YouTube. The locker is secured using a micro-servo and unlocked through set passwords on a keypad. The design makes use of an LCD screen and buzzer to inform users of the results of their inputs.

Because the prototype design is mainly automatic/autonomous, the device's functions are deemed to be functional. Users unlock the SAFE through their own actions and the device responds accordingly. A few non-operating features that will eventually be implemented include the temperature-controlled compartments and the LED lighting system that turns on upon a successful unlock attempt.

A main tradeoff of this design is the fact that there are not enough I/O pins or supply voltage for further components. Our device makes use of the Arduino Uno microcontroller that was previously given in a class starter kit. This Arduino version makes use of the Uno which is a very common starter board. Because of this, there is a large variety of projects and inspiration online that are easy to make use of. However, replacing this board with an Arduino MEGA, for example, allows users to incorporate more components and create more complex circuits/prototypes. However, the MEGA costs about $10-12 more than the Uno, significantly increasing the prototype price.

As mentioned before, we were not able to incorporate our lighting system and temperature control with the Arduino Uno. These components would require their own 12V power supply and further bring up the price of our prototype. As a result, the circuit

for this prototype has been simplified and will not include these systems in this prototype iteration.

Because the prototype of this device is made mainly of plywood, it may be easier to break and more prone to break-ins. Creating a prototype using a metal, steel, or material that is hard to deform or penetrate includes a very complex process. To save time and money, this prototype will make use of wood which is easy to construct and design with.

Future Use

For future use, we would prefer to make it out of a more sturdy material such as metal. Along with that, for ease of use multiple lockers would be made. There is also a possibility of making more compartments for the SAFE so that more food can be stored. Some other improvements that can be made are having a cooling system, bluetooth unlocking, and an LED lighting system. If time permits, we would also like to add an LCD screen that would display the inner temperature of the compartments. The main issues in implementing some of these design changes was the lack of sufficient I/O pins. Therefore, while moving forward and building upon this prototype, we should keep in mind the need for more I/O pins.

Testing

Testing was done throughout the process during each step. We tested different servo motors to see which would best fit our needs in regard to the locking mechanism of our SAFE. We had to experiment with different types of wood as certain plywood was not able to be cut using the laser cutter. We also tested the code required to lock the SAFE and also display a message on the LCD screen.

Strengths

Our project was fully functioning, with a proper lock, keypad and display screen. Furthermore our SAFE is exponentially cheaper than other products on the market. This was so that the food banks would be able to focus their money on getting more food for people in need. The SAFE makes use of multiple compartments, whereas current competitors only use one compartment.

Compromises

Due to insufficient voltage and I/O pins, our project is missing multiple bells and whistles we initially hoped to make use of. To begin with, we could not incorporate bluetooth or fingerprint unlocking. The solenoid lock would've been ideal to implement, however, we could not due to time constraints, and ended up with the traditional servo locking mechanism.

Economics

Food banks play an important role in addressing food insecurity by providing food to individuals in need. Because of this managing and distributing food can be very challenging and put a lot of stress on the organization themselves. Our proposed solution of creating an automated food safe would bring several economic benefits to food banks. We would potentially be able to reduce labor costs, because there would be less of a dependency on staff to be there all the time. Staff will also have more free time to focus on other aspects of the organization like fundraising and outreach. Overall the implementation of this technology will make an organization more efficient.

Conclusion

In conclusion, an automated food safe may become a significant and beneficial tool for food banks. These advantages include less personnel costs, reduced food waste, and enhanced inventory control. Food banks will be able to operate more successfully and efficiently with the use of an automated food safe, helping to combat global food insecurity.

Recommendations

After completing our final prototype and developing this project throughout the term, we came up with several recommendations for the future. Our first recommendation is to use stronger material for the box. We originally prototyped and used laser cut plywood. Some feedback that we received was that the material was not very strong and we completely understood this when creating our initial design. The material we chose for this prototype is easier to work with given the time constraints of the project. If we had more time we could have implemented it, but for now our future recommendation would be to use metal plates that are potentially welded for the safe design.

Another recommendation that we have for the future is more compartments. Currently we only made one safe with two compartments, but this was just for proof of concept. In the future, we intended for this product to have multiple compartments like the package lockers on campus. Another recommendation that we have for the future is low cost material. Some of our competitors that create storage lockers sell the units for around $15-20 thousand dollars. We believe that we can reduce the features to the ones that are most necessary for our application to help food banks save money. Features that would be included would be durability, anti-theft, and a pin database. Finally, our final recommendation would be to find an easier way to implement food lockers. Currently we have only just a basic understanding of how we plan on implementing these lockers. Our future recommendation from this would be to reach out to more food banks and potentially see how they are interested in implementing these systems and the locations that would be most convenient for them.

Future Work

Future iterations of the prototype would include a food requesting system for users to request certain foods that the Food Bank has available. Furthermore, a robbery report system that alerts food bank workers or the Police department would be ideal. Ofcourse, incorporating features that were previously harder/more time consuming to implement, such as the LED lighting system, should be explored. Finally, the ultimate prototypes should be built of much sturdier material, such as metal, in place of the current laser cut plywood walls that the enclosure makes use of.

References

[1] “Food Security and Nutrition Assistance.” USDA ERS - Food Security and Nutrition Assistance, https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/food-security-and-nutrition-assistance/.

[2] “Carty Cupboard - Wesley United Methodist Church.” *FoodPantries.org*, https://www.foodpantries.org/li/carty_cupboard_wesley_united_methodist_church_01608.

Appendices

Appendix A: Food Bank Interview

- The following interview was conducted with a member of the Carty Cupboard Food Pantry at 114 Main St, Worcester, MA 01608.

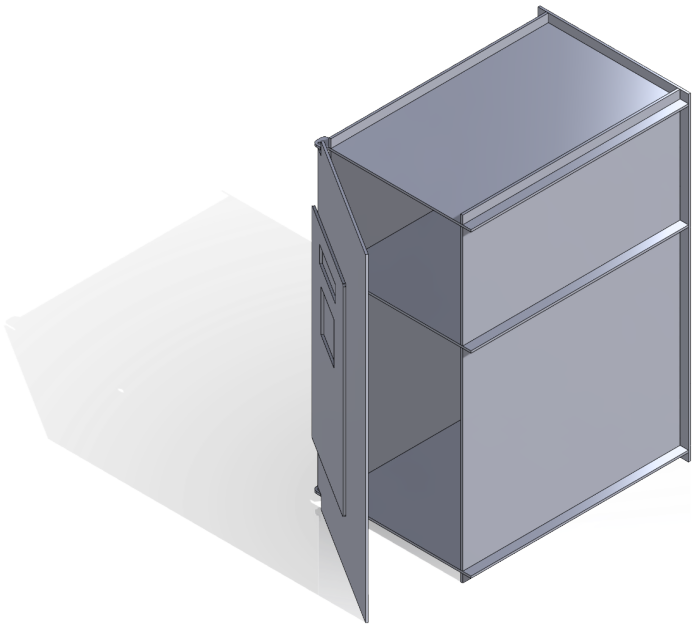
Question	Answer
How easy is it to receive/pick up food?	We serve anybody that comes to the door on Wednesdays from 1-2:30. There is no criteria. They come and say they need food. We can no longer ask for id. All reports are done by zip code. A lot of people may not be here legally so they are wary of giving certain information. Anyone needs food we will give it to them. Technically we are only supposed to serve certain zip codes however we serve everyone regardless because of our mission statement. All I need is the ages of people. I need to just see what age group members of a family fall in. I need to see if they work and stuff like that only really need a zip code. Don't really need a name. If they don't want to write it I just use Jane doe. Just need benefits information and zip code.
Where is food stored for people to pick up?	Food is stored in a separate room that is pretty cool temperature wise and there are multiple shelves. Certain items are pre packed together to make lunches or other meals. Produce and eggs are kept in three large freezers/fridges. One criteria of the food bank is they have to be locked.
Could you benefit from a food locker (similar to Amazon lockers)?	I think it's a really good idea. I think the trouble is implementing how you get the

	numbers and give it to the people. Theoretically they could go anytime. They would have to go through some sort of process to get a code or a fingerprint. We are only open Wednesdays, however there are people hungry all the time. You just have to figure out the logistics.
Is temperature control necessary?	You would have to do a split locker or a refrigerated and non refrigerated section. We also have some non-perishable stuff. You would need to have a refrigerated and non refrigerated section for eggs and meat.
Would you like there to be multiple compartments?	Non refrigerated part for cereal and stuff.
Would Keypad or Fingerprint access be better? What about both?	Either works as long as you figure out the logistics of how to create that system.
Food limit?	They are able to take as much as I have. Some weeks we get 6 or 7 cases of pastries. Sometimes only four. Today we had a lot of sweets and meat so they got to pick two things. Everything fluctuates each week. Today we had a bunch of lotion and deodorant come in.
Do the perishables come in cooked or raw?	Eggs are refrigerated and cheese. Meat is always rock solid frozen.
Do you know where they cook it?	Generally I don't ask but some of them might have a hot plate or a microwave. A lot of them will tell you though.

Appendix B: Team Member Contributions

Name	Contributions
Cristian	Wiring, Prototyping, Laser Cutting, Writing, Creating Slides, Coding
James	Writing, Prototyping, Laser Cutting
Michael	Creating Slides, Writing, Prototyping, Laser Cutting, Coding
Soven	Creating Slides, Writing, Laser Cutting, Wiring

Appendix C: CAD Model



Appendix D: Video Demonstration

https://drive.google.com/file/d/1HuHIDRjmtoTPDOAzq_Hw3dtawZ1vyEzl/view?resourcekey