EML4551-2

Team 508: Portion Perfect

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Abstract

Beth-El Mission is a farmworker ministry located in Wimauma, Florida, and their mission is to support and provide for food-insecure families as well as migrant farmworkers in the community. They distribute dried goods such as rice and beans in quantities of one to four pounds to cater to the Hispanic community that surrounds Beth-El. Currently, Beth-El has two main issues: lifting 50-pound bags of food and distributing even portions.

Team 508's objective is to optimize their distribution process through two unique systems including a scissor lift and a dispenser. The scissor lift will implement a three stage lift capable of reaching the varying dimensions of the pallets of food Beth-El acquires. The scissor lift will feature a winch to drive the platform up and down, as well as castor locks to prevent unwanted movement. The dispenser will shift Beth-El's portion metrics from weight to volume as this conforms to the same metrics used for cooking and reduces inaccuracies that come with approximating.

To prove these designs are effective and efficient, the team is in the process of designing and prototyping a scale model of the lift and dispensing systems to pinpoint any design flaws. The main points of interest for the lift are buckling and tipping; scissor lifts can buckle under load if the scissors are left unsupported. Additionally, adding mass to the lift when it is fully extended will raise its center of gravity, leaving it prone to tipping. The main point of interest for the dispenser is precision; Beth-El currently uses hand scoops and rough approximations for their food servings.

The goal is to enhance efficiency without compromising the social aspect and community spirit at Beth-El Mission.

Keywords: list 3 to 5 keywords that describe your project.

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Acknowledgement

These remarks thanks those that helped you complete your senior design project. Especially those who have sponsored the project, provided mentorship advice, and materials. 4

- Paragraph 1 thank sponsor!
- Paragraph 2 thank advisors.
- Paragraph 3 thank those that provided you materials and resources.
- Paragraph 4 thank anyone else who helped you.

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Notation

NPO	Non-Profit Organization
FEMA	Federal Emergency Management Association

Chapter One: EML 4551C

1.1 Project Scope

1.1.1 Project Description

The objective of this project is to optimize the distribution process of dried goods for Beth-El Mission. We will use mechanical engineering science and design strategies to implement a design that would only add to the current procedure at Beth-El Mission rather than reinventing its current state.

1.1.2 Key Goals

The primary goal of this project is to create a mechanism that will speed up the sorting and distribution process for Beth-El Mission. The device will be able to assist volunteers with lifting and handling of large bulk dry goods to remove the unnecessary strain of heavy lifting. The device will provide the user with the ability to adjust the amount of dry goods dispensed as there will be different sorts of containers and bags distributed. Because the project will be dealing with dry goods and edible products, it is in our best interest to make the device easily sanitized and cleaned. Due to the diverse community that Beth-El Mission is surrounded by it is imperative that the project implements a universal design to alleviate any confusion for its use.

1.1.3 Markets

The purpose of our project is to ease the distribution process of dried goods to food insecure individuals and families who are unable to acquire basic needs for living. This leads our primary market to be comprised of Beth-El mission, other missions, and non-profit organizations (NPO). These organizations specialize in the distribution of dried goods and our project will streamline that process for them. The secondary markets would be parties that would benefit from using the device and they provide a benchmarking basis to acquire targets and metrics. These parties may include the Federal Emergency Management Association (FEMA) and community markets, such as farmer's markets.

1.1.4 Assumptions

To ensure we stay within the scope of the project, it must be known that Beth-El Mission does not need aid in running the distribution process, only in making it more efficient for the volunteers as well as the recipients. This includes the matter at which the dried goods are received and handled, the environment in which the goods are held to ensure the product does not go bad, and that there will be sufficient volunteers to work the stations.

1.1.5 Stakeholders

Stakeholders for the project consist of sponsor Dr. Shayne McConomy, point of contact Mark Orendorf, Dean Suvranu De, and the Beth-El Farmworker Ministry. The stakeholders' guidance will be used for the entire duration of the design process.

Table 1 – Stakeholder Matrix

	Investor	**Decision Maker**	**Advisor**	**Receiver**
Sponsor Dean Suvranu De, Dr. Shayne McConomy	×		×	
Point of Contact Mark Orendorf	×			×
Operators Beth-El Mission		×		×

1.2 Customer Needs

1.2.1 Introduction

In our initial meeting with Mark, he broke down a large majority of Beth-El Mission's distribution process, and answered several of our questions before we were able to ask them. It must be noted that Mark is not a direct representative of Beth-El Mission, he is solely a volunteer who helps during summer and states what he observed during his several visits. Following the meeting, we compiled a list of additional questions that would help in understanding the scope of what Beth-El Mission needs. Below is Table 2, which consists of the response we received from Mark, our interpretation of the response, and how we will focus the project to address those needs.

Table 2 – Customer Needs Question, Response, and Interpretation

Questions	Response	Interpretation
What is the biggest weakness/struggle with the distribution process currently?	"As I have looked at the process I can identify three areas of weakness in bagging the dried goods. One is in the final stage of the bagging." "Roughly one bag out of about 200 breaking." "This leaves the other two weaknesses. One is about the ability of volunteers to lift 50lb bags of dried goods 4 feet high to pour the contents in a Tupperware container. The other weakness is just how time-consuming the bagging process is. The current workspace is a folding table with a bin that can hold up to 100lbs of product, a scale, and space to place a stack of plastic bags."	The project needs to reduce the number of bags breaking. The project needs to safely lift the dried goods. The project needs to reduce the amount of time spent on bagging the dried goods.
How is the food currently being portioned?	"Both the beans and the rice are portioned into two-pound bags from the larger 50lb bags. After a few successful attempts the volunteer will just go by visual filling of the scoop." "I will say that there are rare occasions when Beth-El must stretch the product and will fill 1.5-pound portions. Even more rare, they will portion more than two pounds."	There needs to be consistent variability in the weight being distributed.

<table>
<tr><th>Questions</th><th>Response</th><th>Interpretation</th></tr>
<tr><td>What are the hours of operation for distribution and prep time?</td><td>“The facilities are open Monday through Saturday with Wednesday devoted to distribution and Saturday committed to community outreach and dentistry. This leaves Monday, Thursday, and Friday for Warehouse work sorting and prepping for Wednesday’s distribution. This year distribution is 12:00-5:00 on Wednesdays”.</td><td>The project needs to maximize daily output to account for short windows of operation.</td></tr>
<tr><td rowspan="2">What are the conditions at the distribution site?</td><td rowspan="2">“There are two rooms used for food prep and distribution, a pantry and a multipurpose room.”

“Next door to the pantry is the multipurpose room that is roughly twice the size, allowing for space to sort clothes, diapers, paper products, personal hygiene products, school supplies. This is typically where the bagging of the beans and rice occur.”
“Both rooms are air conditioned and have flooring that can handle heavy foot traffic and pallet jacks. There are plenty of 110 outlets. “

“There is an additional storage space that isn’t air conditioned that has about 20 bins three shelves high large enough for full pallets.”

“The air-conditioned food prep area does not handle the fork lift- just the pallet jacks.”</td><td>The project does not need to be weather resistant.</td></tr>
<tr><td>Dry goods are distributed indoors with ample space.</td></tr>
</table>

Questions	Response	Interpretation
How many volunteers would work each station?	“Typically, 2 stations are run between 9 volunteers. Two individuals scoop dried goods into bags per station while one individual opens bags and another ties the filled bags. The final individual lifts and empties the 50lb bags into the large bins.”	Lower the number of individuals required by each station.
Where are the dried goods acquired from and how much does each bag weigh?	“The USDA (United States Dept. of Agriculture) provides the beans, rice, and typically up to three different canned goods. Most perishable items are donated through local grocery store chains and convenience stores. There is also another ministry that sends large donations as Beth-El is their sole Florida based partner. A smaller portion of donations come from individuals. “ “Beth-El has to register families for tracking and showing the need for the allocations from the USDA.” “Each bag weighs about 50 lbs.”	Beans and rice are delivered to Beth-El so transport assistance from a store to the warehouse is not necessary. The project needs to safely lift the dried goods.
What equipment is currently being utilized at each station?	“You have probably gathered from the previous answers that the equipment is pretty modest. A knife to cut open the bags of beans and rice. A pallet jack to move the pallets. Folding tables, hand scoops, and plastics bins. “	The project needs to be compatible with folding tables of varying heights.

1.2.2 Explanation of Results

We contacted Mark via phone call and email to gain information regarding Beth-El Mission and their needs. Mark was very generous in his responses, but only certain portions of his responses were able to be interpreted as customer needs; the responses deemed not important were removed for the sake of clarity. We gathered that Beth-El Mission has a significant issue with their bagging process, more specifically the bags themselves. Mark stated that about two volunteers are required to separate and open the bags before the dried goods are distributed into them. Moreover, the bags themselves often tear if a volunteer adds more dried goods than the bags can handle. Mark also stated there are less volunteers in the Fall and Winter months, so streamlining the bagging process would lower the number of volunteers required per station. Addressing these issues will aid each station's efficiency and output of dried goods as well as ensuring less waste. The distribution process will take place indoors, so there is no need to be concerned with the weather conditions. There is, however, ample indoor space for a compact system. Beth-El mission uses foldable tables during the distribution process, so the project should be compatible with folding tables of varying heights. Most of the volunteers in the Fall and Winter months are elderly individuals, so lifting large bags of dried goods is potentially dangerous. This issue can be remedied by ensuring that the project can assist in the lifting of these bags.

1.3 Functional Decomposition

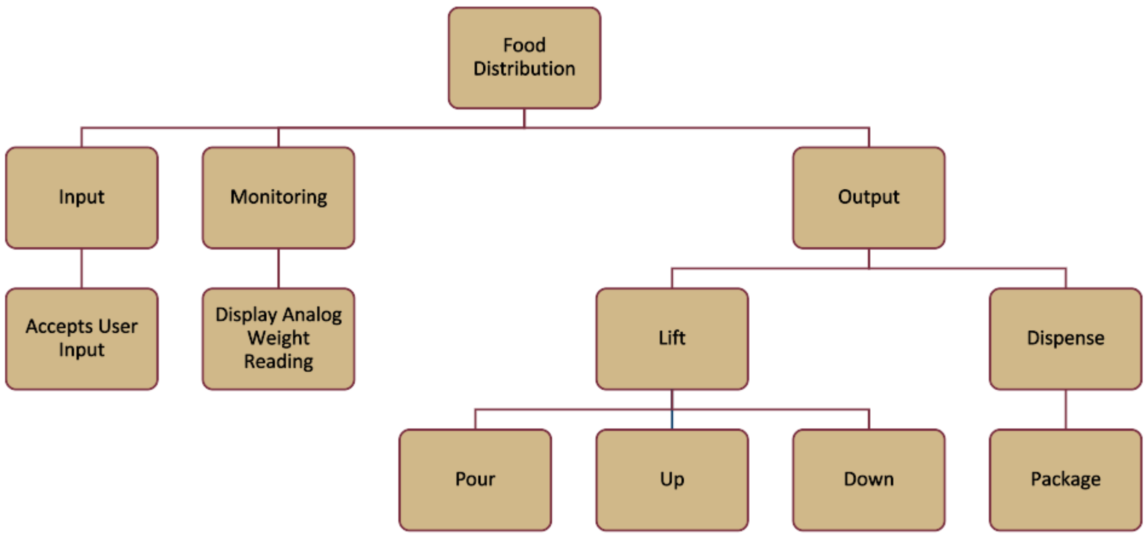
1.3.1 F.D Introduction

Functional decomposition is the process in which we gather our interpreted customer needs and develop a hierarchy chart. The hierarchy breaks down the project into systems, subsystems, and functions. After talking with our sponsor Mark Orendorf, we came up with three major systems. These systems are input from the user, output from the device, and monitoring from an analog reading of the weight of the portioned dry goods back to the user. We discussed this as a group and found that these systems will ultimately achieve the goals of our project.

1.3.2 F.D Flow Chart

The functional hierarchy chart shown below in Figure 1 is the breakdown of all the systems and functions that are system may need to solve the problem. We used ideation to obtain functions that would satisfy the customer needs, then used these for the functional decomposition.

Figure 1 – Functional Hierarchy Chart



Our three main systems are the inputs that drive the device, the output that occurs due to the inputs, and the monitoring system that will weigh the product. Each of these main systems have functions that support their operation. For instance, the *input* system has one function, which is to accept user input; this function helps to drive the outputs. The next system is the *output* system which has two main subsystems. The first subsystem is the lift subsystem. Lift also has three functions that drive the possible motion, and they are up, down, and pour. The second *output* subsystem is the dispense subsystem. The dispense subsystem only has one function which is about the packaging of dried goods.

1.3.3 Smart Integration

Each system has its own functionalities and works independently; however, they also work together to complete a certain task. Below in Table 2 is a cross reference chart that shows how the different systems relate to the different functions.

Table 3 – Cross Reference Chart

Food Distribution			
Function	System		
	Input	Monitoring	Output
Accepts	X		
Display		X	
Pour	X		X
Up	X		X
Down	X		X
Package	X		X

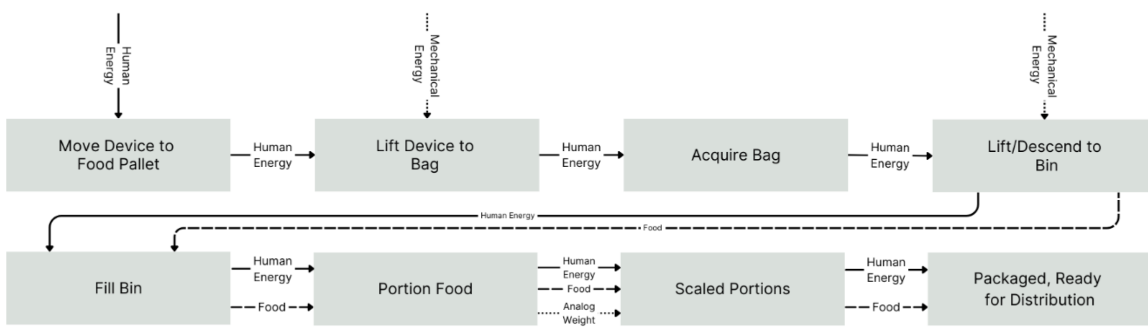
The *accepts* function only pertains to the *input* system since the only action taking place for the function would be the user's input. The *display* function only pertains to the *monitor* system since the function is displaying a reading to the user. The *lift* subsystem contains the functions *up*, *down*, and *pour*. The *up*, *down*, and *pour* functions relate to the *input* system because the user will provide an input for the operation they want from the device. These functions also pertain to *output* because the device will produce an output motion caused by the user's input. The *dispense* subsystem only contains the *package* function. The *package* function relates to both the *input* and the *output* subsystems. This is because the user must provide an input that results in the food being packaged as the output.

1.3.4 Actions and Outcomes

To start the distribution process, the volunteers take 50lb bags of beans or rice and pour them in a large bin. This process is physically straining and will be solved by using the lift function. After the beans are dumped into the bin, the volunteer grabs a scooper and scoops an estimated 1-2 pounds of beans or rice into a plastic bag. This process should be solved with the dispense subsystem which includes the weight and packaging functions. The bag is then handed to the person of interest which concludes the distribution process.

1.3.4 Revised Functional Decomposition Flow Chart

Figure 2 − Revised Functional Decomposition



The functional decomposition chart above more accurately describes the object of our project. The previous design demonstrated a hierarchy chart which would mean that the elements of the project are not subject to the other functions, which is false. The functions of this project must work in a flow…

1.4 Target and Metrics

The functional decomposition of this project listed the functions that the project will need to carry out. These functions will require targets and respective measures to aid in the production and progression of the design path. The measures are parameters for how the functions will be validated, and the targets represent the goal the function must meet. The first iteration of the functional decomposition demonstrates many of the functions the project will be tasked with, but more functions were discussed and generated with a new version of the functional decomposition as well as several clarifications with the customer. The following section will include the critical functions along with the respective targets and metrics. Critical functions are emphasized because these functions ensure that the device will meet the project objective while the rest of the functions allow the project to be a more universal working design.

1.4.1 Critical Targets/Metrics

Below are the critical functions along with the respective targets and metrics:

Table 4 – Critical Target Catalog

Function	Metric	Target
Carrying Capacity	Pounds, lb	$50 \leq x$
Portion Size		$1 \leq x \leq 4$
Pallet Bounds	Height, $in.$	$11 \leq x \leq 60$

1.4.2 Targets/Metrics Derivation

Table 5 – Total Target Catalog

Function	Metric	Target
Carrying Capacity	Pounds, lb	$50 \leq x$
Portion Size		$1 \leq x \leq 4$
Tray Volume	Inches Cubed, $in.^3$	$3520 \leq x$
Storage Volume		$7962 \geq x$
Tilt*	Degrees, x^o	$0 \leq x \leq 21$
Pallet Bounds	Height, $in.$	$11 \leq x \leq 60$
Spout Size*	Diameter, $in.$	$2 \leq x \leq 4$
Lift Velocity*	Meters per Second, $\frac{in}{s}$	$5 \leq x \leq 9$
Compatible Dried Goods*	Listed Dried Goods	Red Beans
		Black Beans
		White Rice

The carrying capacity target was determined from the weight of the bags of rice and beans donated to Beth-El. Each bag weighs approximately 50 pounds therefore, the device needs to be able to carry at least 50 pounds worth of dry goods. The range of portion size targets was determined from our conversations with Mark and Teresita. They told us that the portion size is dependent on how much food they have available that week to distribute, ranging anywhere from 1 to 4 pounds. The target for pallet bounds was determined from the measurements we took of unopened pallets when we visited Beth-El. The pallet has a maximum height of 54.5 inches; we concluded that 60 inches was a good upper bound limit for our device. The lower pallet bound was determined by adding the height of the wooden pallet alone as well as the plastic pallet the wooden pallet sits on; the wooden pallet is 6 inches tall and the plastic one is 5.2 inches therefore, we concluded that 11 inches was a fit lower bound. The three aforementioned functions are the critical functions of this project.

The tray volume function target was determined by taking the volume of a single bag of the dry goods. Through our calculations, we determined that the device needs to be able to hold 3520 cubic inches of dry goods. The storage volume target was determined by taking the interior volume of the Pelican cases, provided to us by Dr. McConomy, that will be used to store the device. The interior volume of each case was found to be 7962 cubic inches. The target tilt angle was determined by performing static analysis on the bag and the lifting surface of the device. The driving variable would be the coefficient of friction; for the value calculated, we used a friction of 0.4 assuming the bag material is similar to paper and the lifting surface is made of steel. The maximum angle of tilt that would prevent the bag from sliding off of the lifting surface was determined to be 21°. After material selection, this value is subject to change. We concluded that the spout size function target should be between 2 and 4 inches. These values will be tested by pouring beans into different sized spouts with a scale under the spouts. The rate at which the dry goods fall onto the scale will be observed and from there, the best diameter will be selected for our design.

The lift velocity target is a safety factor that assumes the device will be automatic in nature and the target ensures the 50-pound bag of rice or beans doesn’t slingshot to the maximum or minimum height. After extensive benchmarking a safe velocity is below 0.5 mph or 8.33 in/s

(Genie). The target range is 5 to 9 in/s to make the lift fast enough to not waste time and slow enough to keep the lift from accelerating to the maximum height in a dangerous manner. The compatible dry goods function target was given to us by Mark and Teresita as these are the dry good that pertain to this project.

1.4.3 Method of Validation

Carrying capacity: We will use CAD software and the known strength values of various materials to ensure that our device can safely support and transport the desired target weight of 50 pounds.

Portion size: A scale will be used to control portion sizes of various dried goods. To ensure the scale being used is valid, a 5-pound weight will be weighed.

Storage volume: The storage volume of the device is set to hold approximately 1 and 2/3 the volume of the largest dried good which is beans.

Tilt: Tilt will be validated in CAD and with a tool such as a protractor.

Pallet bounds: Pallet bounds are set boundaries that were measured on site. These will be validated by ensuring the final design is able to reach these bounds. This will be done in CAD and with a tool like a tape measure.

Spout size: Spout size was determined based on the volumetric flow rate of beans and rice and will be validated by measuring the time it takes to dispense between 1 and 4 pounds of each.

Lift velocity: Lift velocity was determined through benchmarking of similar products and will be tested to ensure safety as well as speed.

Compatible dry goods: Compatible dry goods were determined by Beth-El and will be validated by ensuring all proposed and similar dry goods flow through the device without incident.

1.5 Concept Generation

Following the adjustment of the project's functional decomposition and assignment of targets for the functions, a concept must be drawn. Before arriving to a final concept, the team will accumulate a pool of concepts and ideas (a minimum of 100 concepts) to ensure that novelty and quality are exercised while trying to address the needs of the project. To achieve this number, the team broke their concepts into two primary systems: a lift system and a dispenser system. The team utilized concept generating techniques such as biomimicry, anti-problem, "crap shoot," and conventional brainstorming for, but not limited to, the two systems. The total catalog of all concepts will be in *Appendix E*. After generating 100 concepts, the team rated each concept out of 5, and averaged their scores. Scores with an average rating above 4.0 would be considered for high fidelity concepts, and scores with an average rating above 3.0 would be considered for medium fidelity concepts. Each approved concept will be discussed to ensure that the project's needs are addressed.

1.5.1 Medium Fidelity Concepts

1.5.1.1 Concept 1

Engine Hoist-like Lift & Scale

Concept 1 has an engine-hoist style of lift that has wheels attached to the base. This lift has a hydraulic press that raises and lowers an arm to move a 50-pound bag of food to the needed height. From the lift, the food can be poured into a bin after the bag has been opened and the food can now be distributed. In the bin there is a slanted plate that will guide the falling food to a gate, which will be operated by the volunteer. The gate has a lever that can be opened and closed, by doing so the food will fall into a bag that will be below the spout of the gate. Below the gate the bags will be on a rack, where the volunteers can grab a bag easily and pour the food into it. The bag that has been grabbed by the volunteer should be held over the scale that is below that rack. The scale is a mechanical scale that you can find at Publix in the produce section. From the scale, the food can be weighed and tied off to complete the process.

1.5.1.2 Concept 2

Candy dispenser with a big bin and air displacement lift

Concept 2 has an air displacement lift that will assist the volunteer in getting the bag of food off the top of the pallet to some vertical distance below the bag. The lift uses air in a vacuum sealed container to slow the descent of the payload by smooshing the air together. Utilizing this lift will make it safer for the volunteers to get the food off the topmost part of the pallet. From the lift, the bag can be dropped into a bin that has an inclined plane, which will allow most of the food to collect at the bottom of the bin, where the candy dispenser is stationed at. The candy dispenser works by taking in 1 cup of rice or beans for every turn of the mechanism. This dispenser will change the weight quantity to a volumetric quantity of 1 cup per turn. From the bottom of the dispenser there will be bags attached to a rack, where the volunteer can grab one bag at a time and then fill it to the desired cup range.

1.5.1.3 Concept 3

Large bin with grub screw and pulley system

Concept 3 will have a pulley system where a large mechanical advantage can be created, which will allow the volunteer to either hand crank the bag of food vertically or use a motor attachment to further make the process easier. On the bottom of the lift, four wheels will be attached: 2 standard wheels and 2 castor wheels. The lift can be moved to where the bag needs to be emptied in. Within the bin there will be 2 inclined planes that will meet at the bottom and in between the planes a large grub screw will be ran along the entire middle. The grub screw will catch the food as it turns and dispense the food out the front. Below the bin there will be a rack that holds bags that the volunteer can grab and dispense the food into.

1.5.1.4 Concept 4

Waterwheel dispenser

The waterwheel will alleviate the need for a lift because the food can be caught by the waterwheel at any height and that volunteer can bag it directly from the holder. Each holder of the wheel will have a volume of 1 cup, thus changing the scale factor from weight to volume.

1.5.1.5 Concept 5

Mechanical scale & Foot-powered hydraulic lift

Concept 5 will have a mechanical scale to measure the weight of the food. The scale will be integrated into the system to allow for semi-automatic food portioning. A gate will open whenever the volunteer activates a mechanical lever, releasing food into a bag in the scale area. Once the scale gets to a pre-determined weight, the gate will close automatically until the lever is pulled again. The portioned bag of food can then be removed from the system and set aside for storage. The foot-powered hydraulic lift will allow the volunteers to easily remove 50-pound bags of food from the pallets and transport them to the food distribution bin. The lift will have a foot pedal that can be actuated to raise the lift to the desired height, as well as a valve that can be opened to lower the lift.

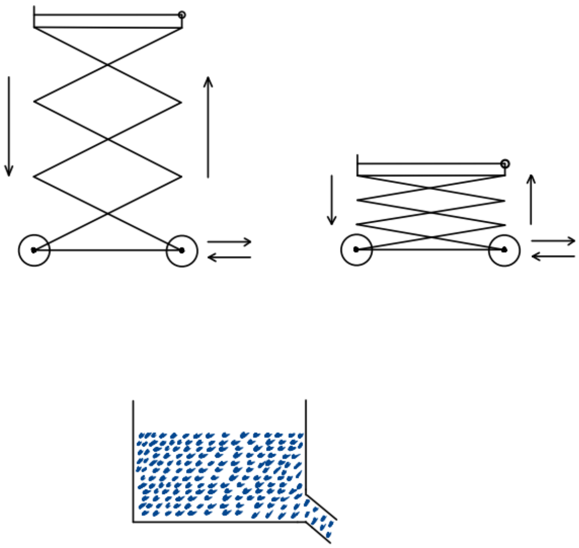
1.5.2 High Fidelity Concepts

1.5.2.1 Concept 6

Scissor lift with rollers and electronic sorting bin

Concept 1 has a thread-driven scissor lift that will move up or down. The vertical motion will allow the volunteers to grab the food from the highest part of the pallet to the lowest part of the pallet. The lift will have 2 regular wheels and 2 castors attached to the bottom so that can easily move. From the lift, the volunteer will be able to take the bag of food to the bin where it is distributed. The electronic sorting bin will automatically portion out the food into pre-set quantities.

Figure 3 – High-Fidelity Concept 1

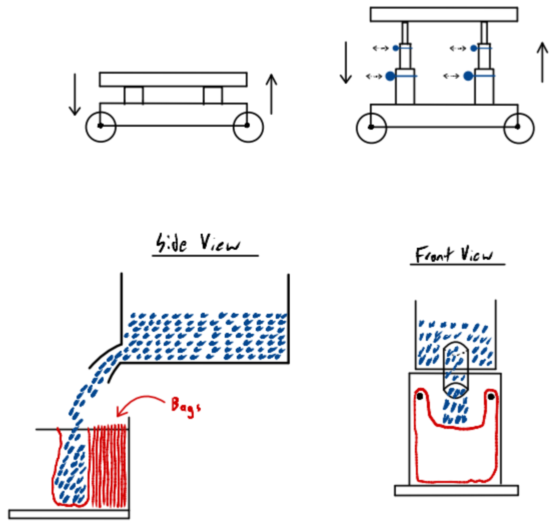


1.5.2.2 Concept 7

Vertically movable stand with dispenser and bag holder

Concept 2 has a vertically movable stand that can be set to different heights and pinned in place. The stand will be able to support the 50-pound bags of food and allow for easier transport from the pallet to the distribution table. The dispenser will allow the food to be dispensed with the pull of a lever or similar mechanism. The dispenser will have a bag holder directly under it that the food can pour into for ease of use.

Figure 4 – High-Fidelity Concept 2

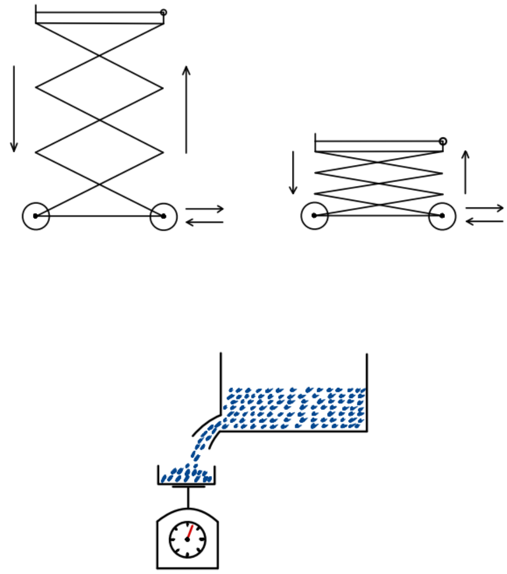


1.5.2.3 Concept 8

Mechanical scale & Scissor lift

Concept 3 has a thread-driven scissor lift that will move up or down. The vertical motion will allow the volunteers to grab the food from the highest part of the pallet to the lowest part of the pallet. The lift will have 2 regular wheels and 2 castors attached to the bottom so that can easily move. From the lift, the volunteer will be able to take the bag of food to the bin where it is distributed. The mechanical scale will allow easy measurement of food. The scale will be integrated into the system to allow for semi-automatic food portioning. A gate will open whenever the volunteer activates a mechanical lever, releasing food into a bag in the scale area. Once the scale gets to a pre-determined weight, the gate will close automatically until the lever is pulled again. The portioned bag of food can then be removed from the system and set aside for storage.

Figure 5 – High-Fidelity Concept 3



1.6 Concept Selection

1.6.1 Introduction to Concept Selection

Concept selection is a helpful process that removes the bias toward a certain concept that the team has taken a liking to. The process entails certain steps to complete the selection process; these steps are a binary pairwise comparison, house of quality, Pugh charts, analytical hierarchy process, and final selection. This process will weigh the medium and high-fidelity concepts to the customer requirements and to the engineering characteristics. By creating all the charts below, there is a higher chance of project success because the bias has been removed.

1.6.2 Binary Pairwise Comparison

The binary pairwise comparison is the first step in concept selection. This process compares the customer requirements to one another, resulting in a weight for each requirement. The customer requirements are listed as one through four in both the horizontal and vertical directions. Row one and column one both have the same requirement, so that box will receive no score. The same applies to row two, column two and so on. Whenever the row is more important than the column, the box receives a “1”. Inversely, when the column is more important than the row, the box will receive a “0”. The binary pairwise comparison gave the customer requirement of “relieving stress from lifting” the highest weight. This weight agrees with the initial priority of the requirement set by the director of Beth-El.

Table 6 – Binary Pairwise Comparison

Customer Requirements	1	2	3	4	Weight Factor
1. Speed up bagging	-	0	0	0	0
2. Relieve stess from lifting	1	-	1	1	3
3. Variable height	1	0	-	0	1
4. Consistent portion system	1	0	1	-	2
Total	3	0	2	1	n - 1 = 3

1.6.3 House of Quality

The House of Quality below in Table 7 was created to find the weight factors of the project’s engineering characteristics vs the customer requirements. The engineering characteristics are carrying capacity, portion size, tray volume, storage volume, tilt, pallet bounds, spout size, lift velocity, and compatible dried goods. Carrying capacity refers to being able to hand a 50-lb bag, portion size refers to the amount dispensed per actuation, tray volume refers to each bag fitting on the tray. Storge volume refers to the amount of tried goods that can fit in a bin, tilt means how far the tray with the bag of food on it can tilt. Pallet bounds refer to how high or low the lift can go, spout size refers to how large or small the dispenser’s hole is, lift velocity refers to how fast the lift can carry the food up or down. Lastly, the compatible dried goods refer to what type of food that the mechanism can work with. In Table 7 the customer requirements are listed to the left under the customer requirements cell. The cell next to it, in green, are the “Importance Weight Factors”, where these weights are taken from the green cell the Binary Pairwise Comparison in Table 6 above. Having the importance weight factors begins the comparison of the customer requirements vs the engineering characteristics. To make the comparison, there is a ranking that displays the importance of the engineering characteristics to the customer’s need, where the ranking goes from 0, 1, 3, 9. 0 has the lowest level of contribution and 9 has the highest level of contribution to the customer requirement. After the engineering characteristics have been ranked, each ranking gets multiplied by the weight factor to the left in green and summed together to make the raw score of the column. The raw scores of each column are summed together to get total raw score, which in this case is 148. With the total raw score, each individual raw score gets divided over the total raw score multiplied by 100 to find each engineering characteristics relative weight factor percentage. Lastly, from the percentages the engineering characteristics were ranked from 1 to 9. The two characteristics that were removed were “Storage Volume” and “Compatible Dried Goods”, because their weight factors were 0 deeming them unimportant.

Table 7 – House of Quality

Engineering Characteristic										
Improvement Direction		↑	↑	↑	-	↑	↑↓	↑	-	-
Units		lb	lb	in^3	in^3	x°	in	in	in/s	N/A
Customer Requirements	**Importance Weight Factor**	**Carrying Capacity**	**Portion Size**	**Tray Volume**	**Storage Volume**	**Tilt**	**Pallet Bounds**	**Spout Size**	**Lift Velocity**	**Compatible Dried Goods**
Speed up bagging	0	0	3	0	3	0	0	3	0	0
Relieve stress from lifting	3	9	0	3	0	9	9	0	3	0
Variable height	1	1	0	0	0	0	9	0	3	0
Consistent portion system	2	0	9	0	0	0	0	9	0	0
Raw Score (148)		28	18	9	0	27	36	18	12	0
Relative Weight %		18.92	12.16	6.08	0.00	18.24	24.32	12.16	8.11	0.00
Rank Order		2	4	7	8	3	1	4	6	9

1.6.4 Pugh Chart

The Pugh charts below compare each of our concepts against a datum concept. The datum or reference concept used for the first Pugh chart is a DURHAND Hydraulic Scissor Lift typically used to service motorcycles as well as a TAYAMA Rice Dispenser. We used both devices in combination as a datum to consider the two main functions our device needs to accomplish, carrying the 50-lb bags of food as well as dispensing and portioning the food. Each medium and high-fidelity concept was compared to the reference concept for each engineering characteristics. If the concept was better than the datum for a certain characteristic, a “+” was entered into the appropriate cell. If the concept was worse than the datum, a “-” was entered into the cell and if both concepts were rated to be the same, an “S” was entered. The total number of “+”s, “-”s, and “S”s were counted, respectively.

Table 8 – First Pugh Chart

		Concepts							
Engineering Characteristics	DURHAND Hydraulic Scissor Lift & TAYAMA Rice Dispenser	Scissor Lift & Scale	Air Displacement Lift & Candy Dispenser	Pulley Lift & Large Bin with Grub Screw	Waterwheel Dispenser	Foot-Powered Hydraulic Lift & Scale	Scissor Lift & Electronic Sorting Bin	Vertically Movable Stand with Bag Holder & Dispenser	Engine Hoist-like Lift & Scale
Carrying Capacity	- DATUM -	-	+	S	-	S	-	S	S
Portion Size		+	+	-	S	+	+	-	+
Tilt		+	+	+	+	+	+	+	+
Pallet Bounds		+	+	+	-	+	+	+	S
Spout Size		S	-	-	-	S	S	S	S
Total Pluses		3	4	2	1	3	3	2	2
Total Satisfactory		1	0	1	1	2	1	2	3
Total Minuses		1	1	2	3	0	1	1	0

The second Pugh chart follows the same process as the first one, but the datum used was the "Scissor Lift & Electronic Sorting Bin". This concept was chosen as the datum after eliminating the 3 lowest ranked concepts. After tallying up the rankings, the "Air Displacement Lift & Candy Dispenser" was eliminated.

Table 9 - Second Pugh Chart

		Concepts			
Engineering Characteristics	Scissor Lift & Electronic Sorting Bin	Scissor Lift & Scale	Air Displacement Lift & Candy Dispenser	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale
Carrying Capacity	- DATUM -	S	-	+	S
Portion Size		-	-	S	-
Tilt		S	S	S	S
Pallet Bounds		S	-	-	S
Spout Size		+	S	+	+
Total Pluses		1	0	2	1
Total Satisfactory		3	2	2	3
Total Minuses		1	3	1	1

1.6.5 AHP

The Analytical Hierarchy Process compares the engineering characteristics against each other to determine their relative importance. This rating matrix uses ratings of 1, 3, 5, 7, and 9. If the column is more important than the row, a value of 3 or greater will be used depending on how much more important it is. If the row is more important than the column, then the inverse of these values will be used. A 1 is used if the row and columns are of equal importance. The [C] Matrix in table 10 determined that the most important engineering characteristic was the pallet bounds. The second highest rated engineering characteristic was the carrying capacity.

Table 10 – [C] Matrix (Analytical Hierarchy Process)

[C] Matrix							
	Analytical Hierarchy Process	A	A	A	A	A	
	Engineering Charactersitic	Carrying Capacity	Portion Size	Tilt	Pallet Bounds	Spout Size	Average
B	Carrying Capacity	1	0.200	0.333	3.000	0.14	0.935
B	Portion Size	5.000	1	5.000	5.000	1	3.400
B	Tilt	3.000	0.200	1	3.000	0.2	1.480
B	Pallet Bounds	0.333	0.200	0.333	1	0.2	0.413
B	Spout Size	7.000	1.000	5.000	5.000	1	3.800
	Total	16.333	2.600	11.667	17.000	2.543	10.029
	Average	3.267	0.520	2.333	3.400	0.509	

This process was continued by comparing the final 3 designs from the Pugh chart in table 9 to each individual engineering characteristic. This was done the same was as it was done in the [C] Matrix from table 10, but with the concepts in place of the engineering characteristics. The results from these matrices were given consistency checks to ensure there was low or no bias in the selection process.

1.6.6 Final Selection

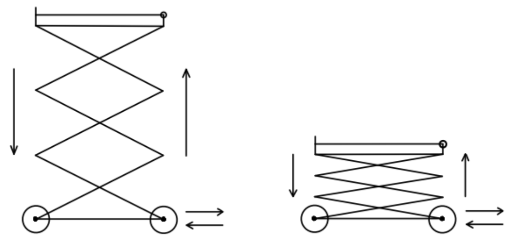
Based on our analysis of the medium and high-fidelity concepts gathered from our concept generation process, it was determined that the “Scissor Lift & Scale” concept best achieves the goals of this project. This was determined through the values we obtained in the alternative value matrix. The higher the alternative value, the better the concept is at meeting the required needs and engineering characteristics of the project. This matrix can be seen in Table 11 below.

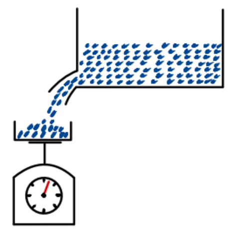
Table 11 – Alternative Value Matrix

Concept	Alternative Value
Scissor Lift & Scale	0.387
Foot-Powered Hydraulic Lift & Scale	0.311
Engine Hoist-like Lift & Scale	0.302

This concept is located below in Figure 6 and has a thread-driven scissor lift that will move up or down. The lift will have 2 regular wheels and 2 castors attached to the bottom so that can easily move. The mechanical scale will allow easy measurement of food. The scale will be integrated into the system to allow for semi-automatic food portioning. A gate will open whenever the volunteer activates a mechanical lever, releasing food into a bag in the scale area. Once the scale gets to a pre-determined weight, the gate will close automatically until the lever is pulled again.

Figure 6 – Scissor Lift & Scale





1.7 Spring Project Plan

Chapter Two: EML 4552C

2.1 Spring Plan

Project Plan.

Build Plan.

Appendices

Appendix A: Code of Conduct

Mission Statement

Team 508 will use the engineering skills they have learned to create a product that solves the problems presented to them by their customers.

Outside Obligations

Alejandro Bendeck has no outside obligations.

Adrian Canepa will be working part time at O'Reilly's Auto Parts. The team will be updated promptly when schedules are released biweekly..

Cody Hayward is a TA for professor Larson and has office hours throughout the week. Due to the high volume of students this semester, Cody will have to set aside more time for grading and the team will be updated promptly.
Jared Sizemore has no outside obligations.

Team Roles

Alejandro Bendeck: Design Engineer
As the Design Engineer, Alejandro will be responsible for designing the devices involved in the project. This could include hand drawings or CAD drawings.

Adrian Canepa: Computational Engineer
As the Computational Engineer, Adrian will be responsible for doing analytical computations as necessary for the project. These could be by hand or through code.

Cody Hayward: Systems Engineer
As the Systems Engineer, Cody will be responsible for the production and management of this project. He will be troubleshooting any issues that occur during this project and will utilize networking with sources to solve the issue.

Jared Sizemore: Manufacturing Engineer
As the Manufacturing Engineer, Jared will be responsible for creating a physical model of the design. This includes prototyping and a final product. He may assist Alejandro in the design of the product if some part of the design isn't practical.

Note: To assign new roles, team members will be required to agree to the role. If not, roles will be decided by chance. If a team member has outside obligations to attend to, the role may be divided between the group.

Communication

Team 508 will utilize Microsoft Teams as their primary form of communication and documentation. All messaging within Teams will pertain to the project and document submission. Those who submit documents will send a screenshot of the submission as proof to the group and for future insurance. Any urgent material that needs attention will be notified within the Teams chat; acknowledgement is important for all messages in the Teams chat. Team members should respond within 23 hours or face potential disciplinary action.

Team 508 will utilize Outlook calendar to schedule meetings with sponsors, Dr. McConomy, and teaching assistants. To avoid scheduling conflicts, the team will send 3 possible time slots to meet.

Team 508 will utilize phone messaging for all other team demands such as fulfilling team duties, standard group meetings, and team bonding.

For Monday Meetings, each member should come to the meeting with questions, ideas, and concerns about the project.

All other meetings should last no longer than 10 minutes unless there are urgent issues to address.

Sponsor meetings should be long enough to understand the full grasp of the project, while remaining short enough to be considerate of everyone's time.

Dress Code

Team 508 will dress casually for informal project meetings and dress formally for virtual design reviews, competitions, and any other presentations; suit and tie is expected. Crazy socks are required. For sponsor and professional meetings, business casual is required.

Attendance Policy

Team 508 will meet every Monday for a MMM (Mandatory Monday Meeting) and Tuesday through Friday as needed. Changes to meeting lengths and dates will be made later if needed to accommodate someone's schedule. Additionally, Monday afternoons at 5:30 will be reserved for a team bonding activity. One time per VDR, the group must meet at Chow Time for group discussion over a meal. Failure to attend a meeting without reasonable advanced notice will result in that individual being required to purchase the next Chow Time meal.

How To Notify Group

Members of Team 508 will communicate in person when possible. Whenever the circumstances don't permit a face-to-face meeting, Microsoft Teams should be used.

Professional Communication

Meetings with our sponsor should be set up through email. The project liaison is Cody Hayward.

What Do We Do Before Contacting Dr. McConomy or Teaching Assistants

Any team decision should be with a vote where majority rules. If the vote is a tie, Bradford Andrews (bma20b@fsu.edu) will be informed of the situation and asked to cast the tie-breaker vote.

At What Point Do We Contact Dr. McConomy

If the situation cannot be resolved with Bradford's vote or input, the team will all go to Dr. McConomy to resolve the situation.

What Do You Want Dr. McConomy to Do When You Go to Him

We would like Dr. McConomy's input on how to resolve the situation.

How to Amend

Unless there is a serious violation, most amendments can be made by purchasing coffee or reserving a pickleball court for the entire group. In the event of a serious violation, Dr. McConomy should be involved in how to proceed.

Award Disbursement

If team 508 wins an award for their project, the winnings will be split five ways. Each team member will receive a fifth of the prize money, with the remaining fifth going to Dr. McConomy to be used for future senior design projects as he sees fit.

Statement of Understanding

By signing this document, the members of this team agree that they have read and agreed to the terms presented in the Code of Conduct. Each member also agrees that they will put their full effort into this project.

X

Alejandro Bendeck

X

Adrian Canepa

X

Cody Hayward

X

Jared Sizemore

Appendix B: Functional Decomposition

Figure 1 – Functional Decomposition Version 1

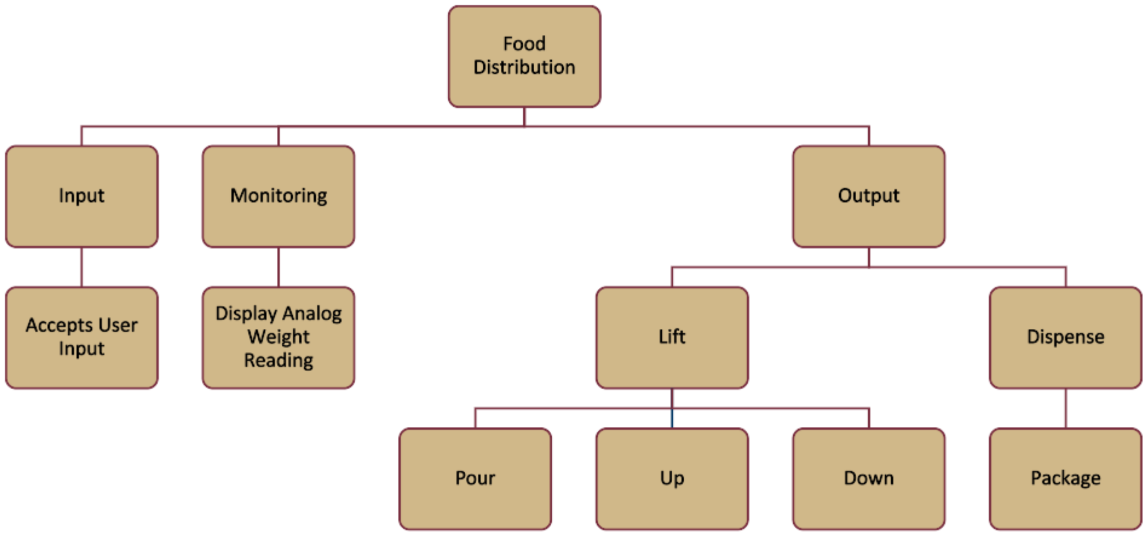
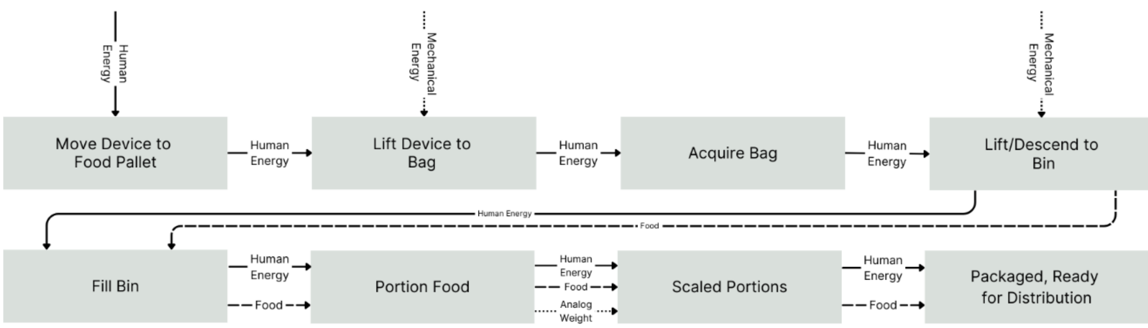


Figure 2 – Functional Decomposition Version 2



Appendix C: Target Catalog

Table 2 – Critical Target Catalog

Function	Metric	Target
Carrying Capacity	Pounds, lb	$50 \leq x$
Portion Size		$1 \leq x \leq 4$
Storage Volume	Inches Cubed, $in.^3$	$3520 \leq x$
Tilt*	Degrees, x^o	$15 \leq x \leq 45$
Pallet Bounds	Height, $in.$	$11 \leq x \leq 60$
Spout Size*	Diameter, $in.$	JARED'S IDEA
Lift Velocity*	Meters per Second, $\frac{in}{s}$	$5 \leq x \leq 9$
Compatible Dried Goods*	Listed Dried Goods	Red Beans
		Black Beans
		Whtie Rice

Table 1 – Total Target Catalog

Function	Metric	Target
Carrying Capacity	Pounds, lb	$50 \leq x$
Portion Size		$1 \leq x \leq 4$
Tray Volume	Inches Cubed, $in.^3$	$3520 \leq x$
Storage Volume		$7962 \geq x$
Tilt*	Degrees, x^o	$0 \leq x \leq 21$

Pallet Bounds	Height, $in.$	$11 \leq x \leq 60$
Spout Size*	Diameter, $in.$	JARED'S IDEA
Lift Velocity*	Meters per Second, $\frac{in}{s}$	$5 \leq x \leq 9$
Compatible Dried Goods*	Listed Dried Goods	Red Beans
		Black Beans
		Whtie Rice

Appendix D: Work Break Down Structure

Fall 2023 Project Plan

Milestone	Tasks	Notes	Duration	Assignee	Date Completed	Status
Code of Conduct						
	Mission Statement	Motivating statement that sets the tone for the group	0.25 days	All		
	Team Roles	Defining the work each member will will be supporting	0.25 days	All		
	Method of Communication	How each member will discuss things together and how each member brings up problems	0.25 days	All		
	Dress Code	This defines how we will dress throughout the project	0.25 days	All		
	Attendance Policy	Explains who needs to meet at certain events	0.25 days	All		
	Statement of Understanding	Write the statement	0.25 days	All		
	Submit Report	Total days and review time →	2 days	Cody		
Project Scope						
	Project Description	The objective of the project	0.25 days	All		
	Key Goals	What we hope to acheive from the device	0.25 days	Alejandro		
	Market	Figure out who will be buying and using the product	0.25 days	Cody		
	Assumptions	This describes what we should assume before we begin the project	0.25 days	Jared		
	Stakeholders	People who will hold stakes in our product and have a voice in certian decisions	0.25 days	Adrian		
	Submit Report	Total days and review time →	2 days	Cody		
Customer Needs						
	Customer Statements	Include questions made to customer as well as customer's statements	1 day	All		
	Interpreted Needs	Customer needs based off the customer's statements	0.5 days	Alejandro		
	Synthesize Data	Written interpretation of customer's needs	0.5 days	Adrian		
	Submit Report	Total days and review time →	3 days	Cody		
Functional Decomposition						
	Introduction of F.D.	Describe the purpose of F.D.	0.25 days	Adrian		
	Discussion of F.D.	Talk about what goes into an F.D.	0.25 days	Cody		
	Identify Major Systems	Introduce the systems of the project	2 days	All		
	Breakdown Subsystems	Go into detail regardging how the subsystems work	2 days	Jared		
	Function Resolution	Smallest element of the needed design system	2 days	Alejandro		
	Submit Report	Total days and review time →	7 days	Cody		
Virtual Design Review 1						
	Insert Project Scope	Create virtual presentation of workpackets above	1 day	Alejandro		
	Insert Customer Needs	↓	1 day	Jared		
	Insert Functional Decomposition	↓	1 day	Cody		
	Submit Report	Total days and practice time →	6 days	Cody		
Targets						
	Define Metrics	How the product will react with the enviroment	2 days	Adrian		
	Define Tests to Validate Metrics	Describe how we will check our metrics	1 day	Jared		
	How Were Metrics Determined	The research on the topics to get our metrics	0.5 days	Alejandro		
	Submit Report	Total days and review time →	4 days	Cody		
Concept Generation						
	100 Concepts	Utilize anti-problem, biomimicry, and morphological chart to generate concepts	2 days	All		
	5 Medium Fidelity	Use piecewise comparison against a competitor	1 day	All		
	3 High Fidelity	Use Piecewise comparison against a datum from previous comparison	1 day	All		
	Submit Report	Total days and review time →	4 days	Cody		

	Concept Selection						
		Binary Comparison	Creates weight factor of customer needs	0.25 days	Alejandro		
		HoQ	Relate engineering characteristics determined by F.D. to the customer requirements	1 day	Adrian		
		Pugh Charts	Compare important engineering characteristics vs. medium and high fidelity concepts	1 day	Jared		
		AHP	Use pairwise comparison to compare engineering characteristics against each other	1 days	Cody		
		Final Selection	Determine best concept, including alternative values, based on the selection process	1 day	All		
		Submit Report	Total days and review time →	5 days	Cody		
	Risk Assessment						
		What Can Go Wrong	TBD				
		Accidents Identified	TBD				
		Steps to Avoid Hazards	TBD				
		Safety Measures	TBD				
		Emergency Response	TBD				
		Emergency Contact	TBD				
		Submit Report	Total days and review time →		Cody		
	Bill of Materials						
		Line Items	TBD				
		Order Needs	TBD				
		Thoroughness of Project	TBD				
		Vendor Identification	TBD				
		Line Item Maturity	TBD				
		Project Maturity	TBD				
		Costs	TBD				
		Submit Report	Total days and review time →		Cody		
	Virtual Design Review 2						
		Insert Targets	Create virtual presentation of workpackets above	1 day	Adrian		
		Insert Concept Generation	↓	1 day	Alejandro		
		Insert Concept Selection	↓	1 day	Jared		
		Insert Risk Assessment	↓	1 day	Adrian		
		Insert Bill of Materials	↓	1 day	Cody		
		Submit Report	Total days and practice time →	7 days	Cody		
	Spring Project Plan						
		Document Timeline	This documentation puts our spring semester on paper so we can see what work is required to have a finished product	2 days	All		
		Submit Report	Total days and review time →	3 days	Cody		
	Poster						
		Layout and Design	TBD				
		Follows Chronological Order	TBD				
		Graphics	TBD				
		Clarity	TBD				
		Poster Completed	TBD				

Appendix E: Concept Generation

Crap Shoot

1. Drone picks up bag into box
2. Catapult
3. Exosuit
4. Magnetic levitation
5. Conveyor system (automated)
6. Candy dispenser with big bin
7. Electronic sorting bin
8. Dolley for food transport
9. Modified storage bin
10. Scissor lift with rollers
11. Large bin with grub screw
12. Nut dispenser
13. Utilize other NPO's for distribution
14. Use forklift to lift weight
15. Hamstring lift machine

Biomimicry

16. Dog tongue scoop
17. Pelican throat scoop
18. Water displacement scale
19. Elephant trunk operating arm

Anti-Problem

20. Request more pallets to reduce pallet height
21. Request smaller weighted bags
22. Rubber mat to wrap around the bags
23. Trained service animal sorting
24. Scooper gloves (gloves that are scoops)
25. Amputee arm scoop attachment

Other Ideas

26. Vertically movable stand with dispenser and bag holder
27. Vending machine dispenser (takes food from bags like a vending machine)
28. Food slide
29. Self service
30. Remote controlled robot
31. Cyclone vacuum system
32. Water based transport system

33. Compressed air lift
34. Balloon powered lift into bin
35. Hand crank winch system lift
36. Take everything to space for easier lifting
37. Autonomous Robot
38. Movable suspension lift
39. Zipline transport system
40. Spring loaded platform for assisted transport
41. Air pillow lift
42. Voice-activated dispenser
43. Smartphone application-controlled dispenser
44. RFID chip-enabled dispenser
45. Waterwheel dispenser
46. Augmented Reality guidance system
47. Amazon drone delivery system
48. Casino-style slot machine
49. Hunger games (fight for food)
50. Wine bag spout

Morphological Chart

Morphological Chart		
Idea:	Dispensers/Scales:	Lifts:
51	Water Displacement Scale	Air Displacement Lift
52	Water Displacement Scale	Engine Lift
53	Water Displacement Scale	Gearbox Lift
54	Water Displacement Scale	Vacuum Lift
55	Water Displacement Scale	Permanent Crane Lift
56	Water Displacement Scale	Linkage Mechanism
57	Water Displacement Scale	Scissor Lift
58	Water Displacement Scale	Pulley System
59	Water Displacement Scale	Foot Powered Hydraulic Lift
60	Water Displacement Scale	Lever System
61	Measurement Cup Scoop	Air Displacement Lift
62	Measurement Cup Scoop	Engine Lift

Morphological Chart		
Idea:	Dispensers/Scales:	Lifts:
63	Measurement Cup Scoop	Gearbox Lift
64	Measurement Cup Scoop	Vacuum Lift
65	Measurement Cup Scoop	Permanent Crane Lift
66	Measurement Cup Scoop	Linkage Mechanism
67	Measurement Cup Scoop	Scissor Lift
68	Measurement Cup Scoop	Pulley System
69	Measurement Cup Scoop	Foot Powered Hydraulic Lift
70	Measurement Cup Scoop	Lever System
71	Mechanical Scale	Air Displacement Lift
72	Mechanical Scale	Engine Lift
73	Mechanical Scale	Gearbox Lift
74	Mechanical Scale	Vacuum Lift
75	Mechanical Scale	Permanent Crane Lift
76	Mechanical Scale	Linkage Mechanism
77	Mechanical Scale	Scissor Lift
78	Mechanical Scale	Pulley System
79	Mechanical Scale	Foot Powered Hydraulic Lift
80	Mechanical Scale	Lever System
81	Digital Scale	Air Displacement Lift
82	Digital Scale	Engine Lift
83	Digital Scale	Gearbox Lift
84	Digital Scale	Vacuum Lift
85	Digital Scale	Permanent Crane Lift
86	Digital Scale	Linkage Mechanism
87	Digital Scale	Scissor Lift

Morphological Chart		
Idea:	Dispensers/Scales:	Lifts:
88	Digital Scale	Pulley System
89	Digital Scale	Foot Powered Hydraulic Lift
90	Digital Scale	Lever System
91	Pelican Throat Scoop	Air Displacement Lift
92	Pelican Throat Scoop	Engine Lift
93	Pelican Throat Scoop	Gearbox Lift
94	Pelican Throat Scoop	Vacuum Lift
95	Pelican Throat Scoop	Permanent Crane Lift
96	Pelican Throat Scoop	Linkage Mechanism
97	Pelican Throat Scoop	Scissor Lift
98	Pelican Throat Scoop	Pulley System
99	Pelican Throat Scoop	Foot Powered Hydraulic Lift
100	Pelican Throat Scoop	Lever System

Appendix F: Concept Selection

Binary Pairwise:

Customer Requirements	1	2	3	4	Weight Factor
1. Speed up bagging	-	0	0	0	0
2. Relieve stess from lifting	1	-	1	1	3
3. Variable height	1	0	-	0	1
4. Consistent portion system	1	0	1	-	2
Total	3	0	2	1	n - 1 = 7

House of Quality:

Engineering Characteristic										
Improvement Direction		↑	↑	↑	-	↑	↑↓	↑	-	-
Units		lb	lb	in^3	in^3	x°	in	in	in/s	N/A
Customer Requirements	Importance Weight Factor	Carrying Capacity	Portion Size	Tray Volume	Storage Volume	Tilt	Pallet Bounds	Spout Size	Lift Velocity	Compatible Dried Goods
Speed up bagging	0	0	3	0	3	0	0	3	0	0
Relieve stress from lifting	3	9	0	3	0	9	9	0	3	0
Variable height	1	1	0	0	0	0	9	0	3	0
Consistent portion system	2	0	9	0	0	0	0	9	0	0
Raw Score (148)		28	18	9	0	27	36	18	12	0
Relative Weight %		18.92	12.16	6.08	0.00	18.24	24.32	12.16	8.11	0.00
Rank Order		2	4	7	8	3	1	4	6	9

HoQ Relative Weight Factor:

Engineering Charactersitics	Relative Weight (%)	Rank	Criteria (Average)
Carrying Capacity	18.92	2	11.11
Portion Size	12.16	4	
Tray Volume	6.08	7	
Storage Volume	0.00	8	
Tilt	18.24	3	
Pallet Bounds	24.32	1	
Spout Size	12.16	4	
Lift Velocity	8.11	6	
Compatible Dried Goods	0.00	9	

Pugh Charts:

		Concepts							
Engineering Characteristics	DURHAND Hydraulic Scissor Lift & TAYAMA Rice Dispenser	Scissor Lift & Scale	Air Displacement Lift & Candy Dispenser	Pulley Lift & Large Bin with Grub Screw	Waterwheel Dispenser	Foot-Powered Hydraulic Lift & Scale	Scissor Lift & Electronic Sorting Bin	Vertically Movable Stand with Bag Holder & Dispenser	Engine Hoist-like Lift & Scale
Carrying Capacity	- DATUM -	-	+	S	-	S	-	S	S
Portion Size		+	+	-	S	+	+	-	+
Tilt		+	+	+	+	+	+	+	+
Pallet Bounds		+	+	+	-	+	+	+	S
Spout Size		S	-	-	-	S	S	S	S
Total Pluses		3	4	2	1	3	3	2	2
Total Satisfactory		1	0	1	1	2	1	2	3
Total Minuses		1	1	2	3	0	1	1	0

		Concepts			
Engineering Characteristics	Scissor Lift & Electronic Sorting Bin	Scissor Lift & Scale	Air Displacement Lift & Candy Dispenser	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale
Carrying Capacity	- DATUM -	S	-	+	S
Portion Size		-	-	S	-
Tilt		S	S	S	S
Pallet Bounds		S	-	-	S
Spout Size		+	S	+	+
Total Pluses		1	0	2	1
Total Satisfactory		3	2	2	3
Total Minuses		1	3	1	1

AHP Main [C] Matrix:

[C] Matrix							
	Analytical Hierarchy Process	A	A	A	A	A	
	Engineering Charactersitic	Carrying Capacity	Portion Size	Tilt	Pallet Bounds	Spout Size	Average
B	Carrying Capacity	1	0.200	0.333	3.000	0.14	0.935
B	Portion Size	5.000	1	5.000	5.000	1	3.400
B	Tilt	3.000	0.200	1	3.000	0.2	1.480
B	Pallet Bounds	0.333	0.200	0.333	1	0.2	0.413
B	Spout Size	7.000	1.000	5.000	5.000	1	3.800
	Total	16.333	2.600	11.667	17.000	2.543	10.029
	Average	3.267	0.520	2.333	3.400	0.509	

AHP Main norm[C] Matrix:

norm[C] Matrix							
	Analytical Hierarchy Process	A	A	A	A	A	
	Engineering Characteristic	Carrying Capacity	Portion Size	Tilt	Pallet Bounds	Lift Velocity	Critical Weight {W}
B	Carrying Capacity	0.061	0.077	0.029	0.176	0.056	0.080
B	Portion Size	0.306	0.385	0.429	0.294	0.393	0.361
B	Tilt	0.184	0.077	0.086	0.176	0.079	0.120
B	Pallet Bounds	0.020	0.077	0.029	0.059	0.079	0.053
B	Spout Size	0.429	0.385	0.429	0.294	0.393	0.386
	Total	1.000	1.000	1.000	1.000	1.000	1.000

AHP Main [Pi] Matrix:

[Pi] Matrix				
	Analytical Hierarchy Process	A	A	A
	Engineering Charactersitic	Scissor Lift & Scale	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale
B	Carrying Capacity	0.724	0.193	0.083
B	Portion Size	0.333	0.333	0.333
B	Tilt	0.633	0.260	0.106
B	Pallet Bounds	0.074	0.283	0.643
B	Spout Size	0.333	0.333	0.333

AHP Main Consistency Check:

Consistency Check					
Weighed Sum Vector {Ws} = [C]{W}	{W}	Cons = {Ws}./{W}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
0.405	0.080	5.075	5.384	0.096	0.087
2.011	0.361	5.566			
0.667	0.120	5.548			
0.269	0.053	5.103			
2.171	0.386	5.627			

AHP Main Alternative Value Matrix:

Concept	Alternative Value
Scissor Lift & Scale	0.387
Foot-Powered Hydraulic Lift & Scale	0.311
Engine Hoist-like Lift & Scale	0.302

AHP EC [C] Matrices:

[C] Matrix for Carrying Capacity					
	Analytical Hierarchy Process	A	A	A	
		Scissor Lift & Scale	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale	Average
B	Scissor Lift & Scale	1	5.000	7.000	4.333
B	Foot-Powered Hydraulic Lift & Scale	0.200	1	3.000	1.400
B	Engine Hoist-like Lift & Scale	0.143	0.333	1	0.492
	Total	1.343	6.333	11.000	6.225
	Average	0.448	2.111	3.667	

[C] Matrix for Portion Size					
	Analytical Hierarchy Process	A	A	A	
		Scissor Lift & Scale	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale	Average
B	Scissor Lift & Scale	1	1.000	1.000	1.000
B	Foot-Powered Hydraulic Lift & Scale	1.000	1	1.000	1.000
B	Engine Hoist-like Lift & Scale	1.000	1.000	1	1.000
	Total	3.000	3.000	3.000	3.000
	Average	1.000	1.000	1.000	

[C] Matrix for Tilt					
	Analytical Hierarchy Process	A	A	A	
		Scissor Lift & Scale	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale	Average
B	Scissor Lift & Scale	1	3.000	5.000	3.000
B	Foot-Powered Hydraulic Lift & Scale	0.333	1	3.000	1.444
B	Engine Hoist-like Lift & Scale	0.200	0.333	1	0.511
	Total	1.533	4.333	9.000	4.956
	Average	0.511	1.444	3.000	

[C] Matrix for Pallet Bounds					
	Analytical Hierarchy Process	A	A	A	
		Scissor Lift & Scale	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale	Average
B	Scissor Lift & Scale	1	0.200	0.143	0.448
B	Foot-Powered Hydraulic Lift & Scale	5.000	1	0.333	2.111
B	Engine Hoist-like Lift & Scale	7.000	3.000	1	3.667
	Total	13.000	4.200	1.476	6.225
	Average	4.333	1.400	0.492	

[C] Matrix for Spout Size					
	Analytical Hierarchy Process	A	A	A	
		Scissor Lift & Scale	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale	Average
B	Scissor Lift & Scale	1	1.000	1.000	1.000
B	Foot-Powered Hydraulic Lift & Scale	1.000	1	1.000	1.000
B	Engine Hoist-like Lift & Scale	1.000	1.000	1	1.000
	Total	3.000	3.000	3.000	3.000
	Average	1.000	1.000	1.000	

AHP EC norm[C] Matrices:

norm[C] Matrix for Carrying Capacity					
	Analytical Hierarchy Process	A	A	A	
		Scissor Lift & Scale	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale	Design Alternative Priorities {Pi}
B	Scissor Lift & Scale	0.745	0.789	0.636	0.724
B	Foot-Powered Hydraulic Lift & Scale	0.149	0.158	0.273	0.193
B	Engine Hoist-like Lift & Scale	0.106	0.053	0.091	0.083
	Total	1.000	1.000	1.000	1.000

norm[C] Matrix for Portion Size					
	Analytical Hierarchy Process	A	A	A	
		Scissor Lift & Scale	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale	Design Alternative Priorities {Pi}
B	Scissor Lift & Scale	0.333	0.333	0.333	0.333
B	Foot-Powered Hydraulic Lift & Scale	0.333	0.333	0.333	0.333
B	Engine Hoist-like Lift & Scale	0.333	0.333	0.333	0.333
	Total	1.000	1.000	1.000	1.000

norm[C] Matrix for Tilt					
	Analytical Hierarchy Process	A	A	A	
		Scissor Lift & Scale	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale	Design Alternative Priorities {Pi}
B	Scissor Lift & Scale	0.652	0.692	0.556	0.633
B	Foot-Powered Hydraulic Lift & Scale	0.217	0.231	0.333	0.260
B	Engine Hoist-like Lift & Scale	0.130	0.077	0.111	0.106
	Total	1.000	1.000	1.000	1.000

norm[C] Matrix for Pallet Bounds					
	Analytical Hierarchy Process	A	A	A	
		Scissor Lift & Scale	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale	Design Alternative Priorities {Pi}
B	Scissor Lift & Scale	0.077	0.048	0.097	0.074
B	Foot-Powered Hydraulic Lift & Scale	0.385	0.238	0.226	0.283
B	Engine Hoist-like Lift & Scale	0.538	0.714	0.677	0.643
	Total	1.000	1.000	1.000	1.000

norm[C] Matrix for Spout Size					
	Analytical Hierarchy Process	A	A	A	
		Scissor Lift & Scale	Foot-Powered Hydraulic Lift & Scale	Engine Hoist-like Lift & Scale	Design Alternative Priorities {Pi}
B	Scissor Lift & Scale	0.333	0.333	0.333	0.333
B	Foot-Powered Hydraulic Lift & Scale	0.333	0.333	0.333	0.333
B	Engine Hoist-like Lift & Scale	0.333	0.333	0.333	0.333
	Total	1.000	1.000	1.000	1.000

AHP EC Consistency Checks:

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
2.273	0.724	3.141	3.066	0.033	0.063
0.588	0.193	3.043			
0.251	0.083	3.014			

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
1.000	0.333	3.000	3.000	0.000	0.000
1.000	0.333	3.000			
1.000	0.333	3.000			

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
1.946	0.633	3.072	3.039	0.019	0.037
0.790	0.260	3.033			
0.320	0.106	3.011			

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
0.222	0.074	3.013	3.066	0.033	0.063
0.866	0.283	3.062			
2.008	0.643	3.121			

Consistency Check					
Weighed Sum Vector {Ws} = [C]{Pi}	{Pi}	Cons = {Ws}./{Pi}	Average Consistency (λ)	Consistency Index (CI)	Consistency Ratio (CR)
1.000	0.333	3.000	3.000	0.000	0.000
1.000	0.333	3.000			
1.000	0.333	3.000			

References

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