GNG1103

Final Design Report

The MakerSpace Machine

**Group C5**

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# Abstract

In the winter term of 2019, group C5 was tasked with the assignment to construct the distribution aspect of a functional automated kitchen. With 5 group members in varying engineering disciplines, the team began brainstorming different designs that met the design criteria we were initially given. Thereon, by meeting with the client on multiple occasions, design specifications were discussed and a problem statement was formulated that met the clients refined needs. As a collective, the following problem statement was created: “to construct an automated cooking device that will replace unskilled employees in the food industry that will be cost efficient, safe, time proficient, customizable and consistent when creating food for the customer”.

Once a problem statement was developed, the team decided to benchmark existing automated kitchen’s currently present in the market to help determine what solutions we thought were most viable that we could build off of. Analyzing different metrics, construction of our first conceptual design began based off of multiple freehand sketches and online models of existing automated kitchen features. The group then proceeded to present the initial solution to the client to receive feedback, where upon it was given contrasting views and we were instructed to go back to the drawing board as our design was not feasible. Following the departure of two of our group members and multiple group meetings with the PM, two new prototypes were developed - both of which were better received by the client. At this point, it was possible to create an estimated cost of our track system and a basic project plan that was updated weekly. The design was improved upon on a weekly basis to keep up with problems that were encountered with the design, and to change the project plan set in place to incorporate certain problems and adding new tasks that came up along the way.

This report details the process of designing the system from the empathising stage to the prototyping and testing stage, while highlighting constraints and challenges faced along the way.

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# Introduction

This project was primarily inspired by the current situation revolving around the restaurant industry. Due to problems in the industry such as unskilled employees, a reduced workforce, and corporate firms leaning to secure more profit, automated cooking devices have begun replacing unfavourable workers in order to increase profit. Not only does this provide more reliability when serving consistent meals, but increased safety and accuracy when delivering a meal to different patrons. In addition, as restaurants are able to secure more profit given the lack of labor payment, the cost per meal is driven down which strongly appeals to consumers and food is distributed both more efficiently and sustainably.

The challenge was to construct the distribution aspect of a fully functional automated kitchen that was cost efficient, safe, time proficient, customizable and consistent when creating food for the customer. This design revolved around the concept of transportation involved in the cooking process, whereby distinct recipe ingredients were transported in a timely manner from a bulk container to a induction heated cooking pot. During this stage, it remained essential that zero compromises were made as the safety of the consumer was of top priority. This meant all recipe ingredients were temperature controlled and transport vessels were appropriately cleaned after each and every use. However, with a shortage of group members, it was important to prioritize the design’s needs, focussing on a moving sensor that would actively dispense controlled portions of recipe ingredients and weight sensor that would measure precise amounts of food.

Sticking to the five fundamental steps of design thinking process to better analyze the issue, a working solution was created within allocated time and budget. The final prototype was one centralized over the ideas of bulk containment, a rigid and stationary stand to ensure stability while minimizing square footage, rotating motors that slowly dispensed recipe ingredients, and a weight sensor that measured a precise amount of food. Key aspects that made our design unique and different from devices currently available on the market were moving servo motors that dispensed consistent portions of food, a working code that was timed to precision when weighing ingredients, a creative user interface that allowed consumer customization, and a low minimal square footage area that allowed for a compact structure.

# Client Needs

The client, Patrick Genest is the Director of Food, Card and Conference Services at the University of Ottawa and has over 35 years of experience in the food service industry. Since Patrick has worked at various levels of the food industry, including working in the kitchen at fast food restaurants, helping to open food chains and restaurants as well as working with catering services, the client has a vast understanding of the inner workings of the industry and what customers require in terms of service in order to be satisfied. This means that the client has high expectations for the product that is being created.

Taking inspiration from SPYCE, which is an already existing automated food distribution system, the client wishes to create a kitchen on the University of Ottawa campus that could provide customers with food in a timely manner, but without the need for human interaction. The kitchen in mind would not require employees to measure or cook the food. Humans would only be required to prepare the ingredients, chopping vegetables for example, and to add the finishing touches to dishes such as adding toppings. An automated kitchen reduces the chances of human error and reduces the dependencies of having skilled workers in the kitchen and in the labour pool of this particular industry. An automated kitchen would also be able to eliminate possible cross-contamination of ingredients meaning that this method of preparing food would be ideal for customers with food allergies or specific preferences.

According to the customer, the ideal machine would measure each specific ingredient required in the recipe, and then transport the ingredients, which are pre-cut and if necessary pre-cooked, into a pan in the order indicated by the recipe. The machine would then cook the ingredients for the necessary amount of time required for each ingredient, and this prepared food will be transferred into a serving dish to be given to the customer. Final touches such as sauces or fresh toppings, as well as the addition of a lid atop the serving dish would be executed by an employee. The scope of the product is focused on the distribution aspect of the product, which refers to the machine’s ability to measure and distribute the ingredients to the cooking pot.

The specific requirements, according to the customer, for the product are:

* The machine must be able to measure and distribute all of the ingredients included in the provided recipes.
* The machine must be able to omit certain ingredients from the recipe, upon the customer's request.
* Ingredients will be added in the order indicated in each recipe.
* Cooking time will be as minimal as possible in order to provide fast customer service.
* All portion sizes of meal will be the same.
* The machine will meet sanitary standards meaning that all components that come in contact with the food are easily taken apart in order to sanitize.
* Parts must be easily interchangeable and easily repaired.
* Maintenance should not take extensive amounts of time or many people to do the work.
* Ingredients must be kept at the correct temperature before they are set to be cooked. The correct temperature refers to not being in the critical zone (from 4℃ to 60℃).
* All components of the machine that come in contact with food will be a food grade material.
* The machine must be aesthetically pleasing and interesting to watch.
* The machine must utilize space well. This means that both height and vertical span of the product will be considered.

# Problem Statement

To construct an automated cooking device that will replace unskilled employees in the food industry that will be cost efficient, safe, time proficient, customizable and consistent when creating food for the customer.

# Design Criteria

The design criteria that you developed (and an explanation of the metrics and target specifications that you used) to select your chosen approach.

### Table 1: Benchmarking of 3 Different Products

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Metric #** | **Need #** | **Metric** | **SPYCETM** | **MegCookTM** | **CreatorTM** |
| 1 | 1 | Cost (per portion in CAD) | $10.00 | $6.50 | $7.25 |
| 2 | 2 | Usage of Electricity | N/A | N/A | N/A |
| 3 | 3 | Food Temperature Range | N/A | N/A | < 40° < x < 140° |
| 4 | 4 | Time Proficiency | Under 3 min | Under 10 min | Under 5 min |
| 5 | 5 | Complexity in operation (systems) | High | Medium | Low |
| 6 | 6 | Square Footage | 20 sq.ft | 30 sq.ft | 25 sq. ft |
| 7 | 7 | Maintenance | $10.00 | $6.50 | $7.25 |

Cost (per portion in CAD)

Make money back sooner will be better as profits will arrive quicker.

Usage of Electricity

Low usage of electricity can have a significant impact long term.

Food Temperature Range

Food temperature range should be outside of Danger Zone to avoid food poisoning, which can lead to a poor reputation.

Time Proficiency

A machine that prepares food quickly will translate to a lower wait time for the customers. High wait times might be discouraging to customers who have never tried food from the machine.

Complexity in operation (systems)

Lower complexity means less maintenance and easy to clean parts.

Square Footage

Buying or renting space can be expensive, so lower square footage would be cheaper.

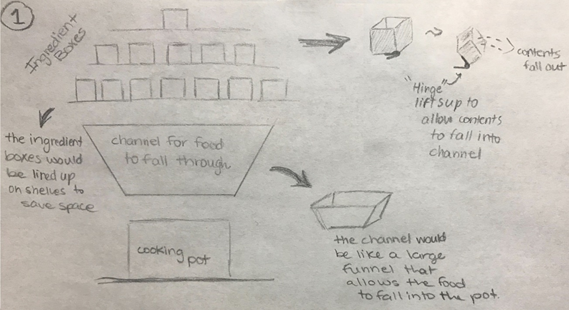
Maintenance

Ideally low-cost and low-maintenance would be preferred as it would not be very efficient for the machine to be frequently under maintenance and not preparing meals.

# Design Ideas

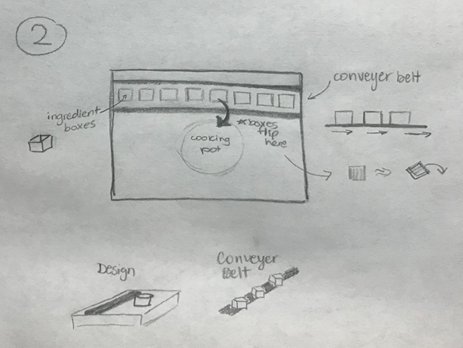
In order to find a solution for the problem at hand, brainstorming was essential for determining what a solution to the problem would look like. This was done by creating sketches of the solution concepts generated. Various solutions that were considered are shown below the descriptions.

This design consists of shelves which each have multiple ingredient boxes located on them. The shelves sit atop a large funnel that will act as a channel for the ingredients to fall through in order to reach the cooking pot. The ingredient boxes will be fastened to a hinge that will tip the boxes to allow the contents to fall from the ingredient boxes, into the channel and then into the pot.



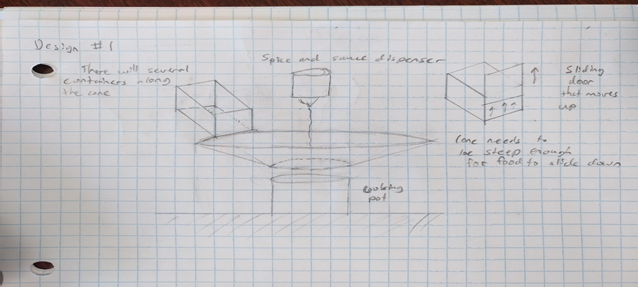
#### Figure 1: Design 1

This design consists of a conveyor belt with ingredient boxes that will tip over to empty their contents once they are in front of the cooking pot. The ingredients would be lined up in the order in which they are supposed to be added into the cooking vessel, and spaced apart to account for the different cooking times for each ingredient. The conveyor belt would be reset each time a new meal is being made.



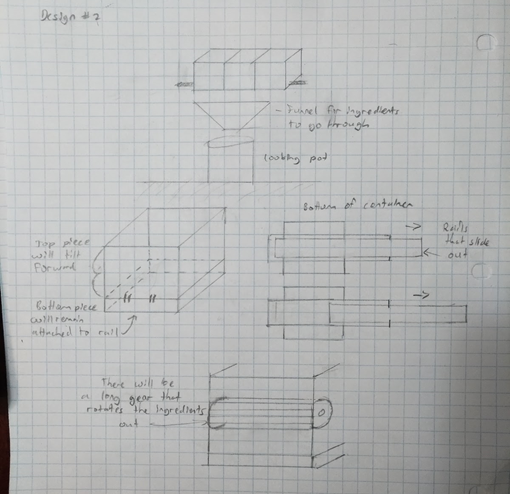
#### Figure 2: Design 2

This design’s main feature of distributing food is by letting food slide down into the cooking pot. There will be a large cone above the pot with each ingredient separated by their respective containers. Each container will have a sliding door that opens and closes for a certain amount of time to let the ingredients to slide out naturally. Sauces and spices that may not slide down the cone that easily will be dispensed above the pot.



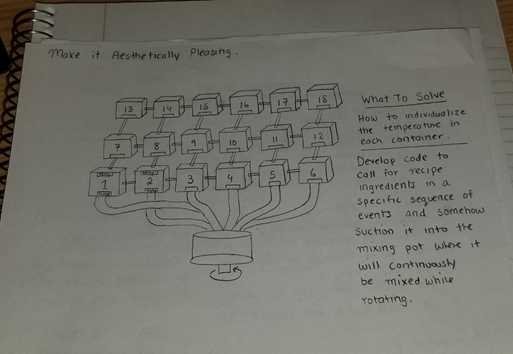
#### Figure 3: Design 3

This design has all the ingredients in containers in two long rows that shifts side to side according which ingredient needs to be dispensed. All the containers will be held together and will slide back and forth on something similar to drawer slides. Each ingredient is dispensed through a rotating gear that varies in size depending on the ingredient. The rotating gear ensures that the amount of ingredients added is more consistent.



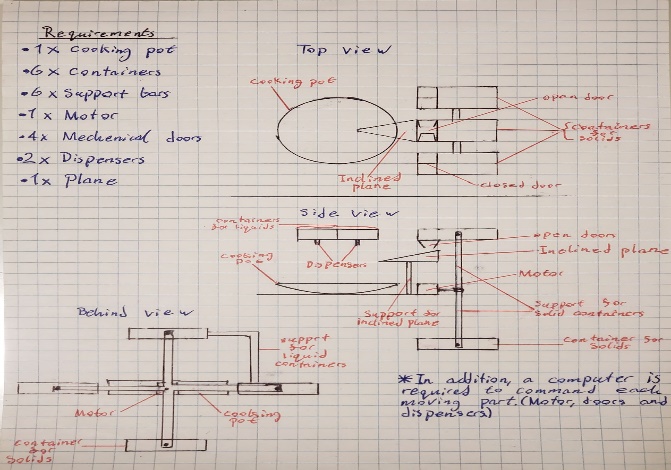
#### Figure 4: Design 4

This design uses 18-24 compartmentalized containers each containing a distinct ingredient for the recipes provided. Each container will be temperature controlled using the temperature control meter shown to us through an Arduino program. At the bottom of each container are circular disks that slide when each ingredient is called for (using C++ code to ensure each ingredient is called in a timely manner and evenly cooked). The disks will spill each container’s content into pipes that lead the food into an induction heated pot that rotates to sear the food. Thereon, it is tilted onto a plate where it is picked up by hand and garnished with all the customer's preferences.

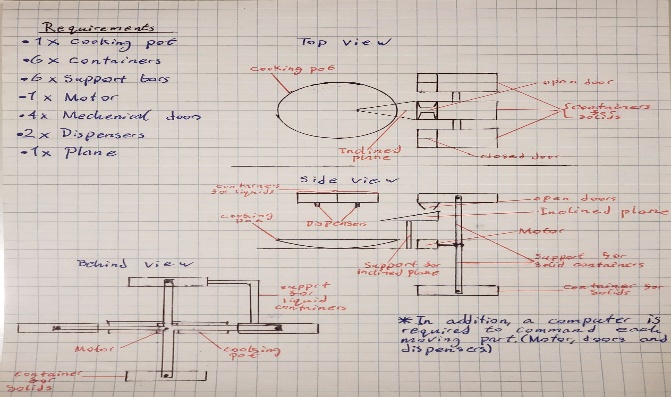


#### Figure 5: Design 5

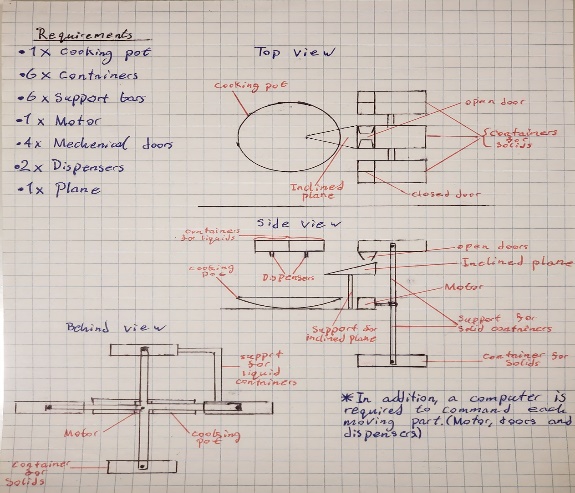
After considering many ideas, it was a particular idea that stood out as being unique and interesting, while still getting the job done. This concept was chosen to create our first prototype. This idea consisted of having stationary cooking pots that would be supplied with ingredients using a rotating axis, similar to a Ferris wheel, which would be stationary and rotate to get the bulk containers of each ingredient to the top of the rotation. Once the bulk container reached the top of the rotation, the ingredient in the box would be released from the bulk container and into the cooking pot. The measurement of the ingredients was dependant on time, and measured through various trials which would determine the exact way to measure this particular ingredient.



#### Figure 6: Design 6 Top View



#### Figure 7: Design 6 Side View



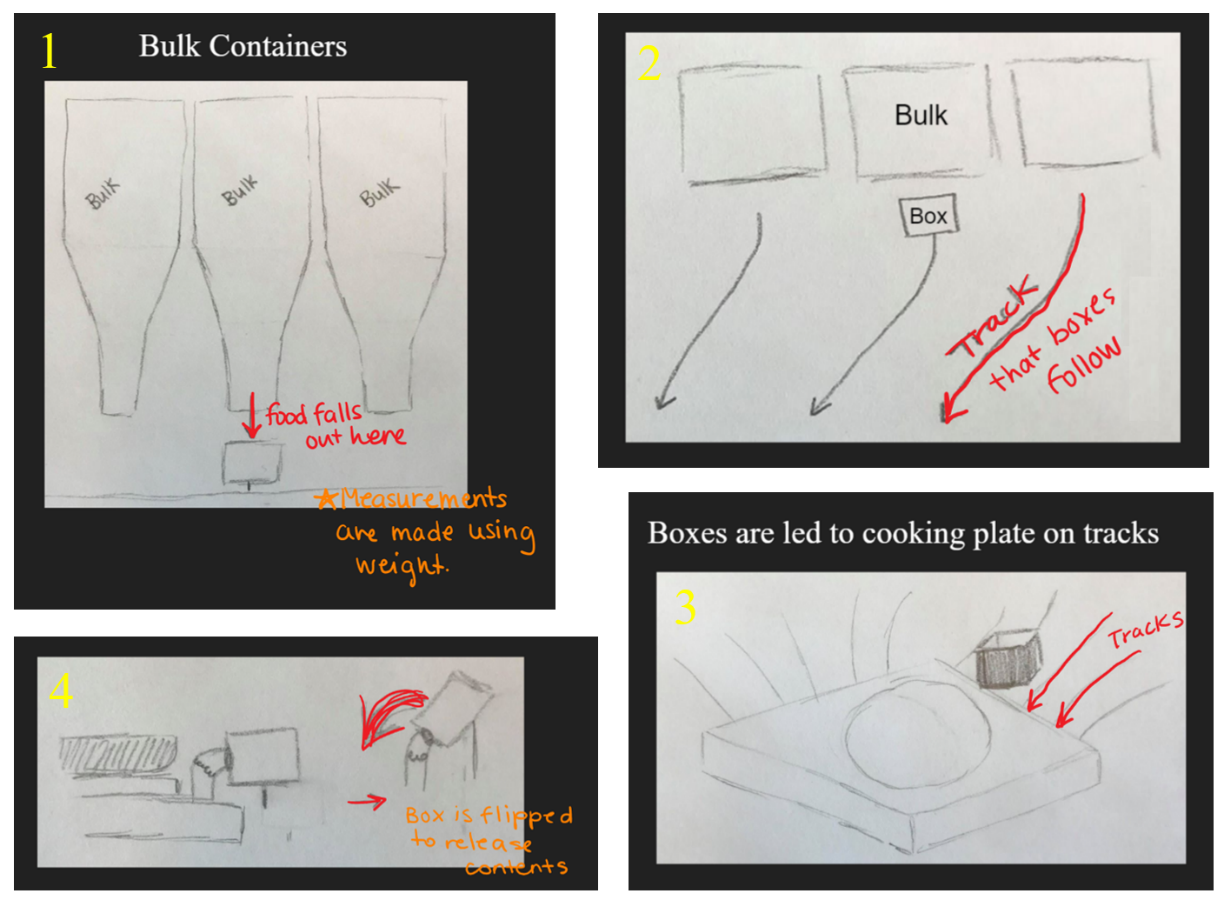
#### Figure 8: Design 6 Behind View

# Chosen Solution

In order to solve the problem at hand, prototyping was a useful asset while exploring ideas. Prototype I was made of scrap materials. The idea consisted of having stationary cooking pots that would be supplied with ingredients using a rotating axis, similar to a Ferris wheel, which would be stationary and rotate to get the bulk containers of each ingredient to the top of the axis. Once the bulk container reached the top of the rotation, the ingredient in the box would be released from the bulk container and into the cooking pot. The measurement of the ingredients was dependant on time, and the time required to measure each ingredient would be determined through various trials which would determine the exact way to measure this particular ingredient. The concept relied on the idea that if the door being opened for one second yielded a cup of food and a cup and half of the ingredient was desired, the door would then be opened for a second and a half.

This design was flawed and is different than the method of measurement used in the final concept because the design relied on time to measure the ingredients. Time based measurement was eventually viewed as the least desirable option for measurement because the flow rate of all ingredients would change based on how full the bulk container was. A full container would have a exit flow much faster than a container that was half full. Prototype I was also flawed because the rotating axis would be required to support a large amount of weight, considering it would have to sustain the bulk containers for all of the ingredients required for the recipe. As the client expressed the desire to have the bulk containers supply food for extended periods of time, this would mean that the bulk containers would need to be large and would be heavy. Each pot in this design would also be stationary, meaning that each bulk setup would have to be specific to each recipe. This was not desirable for the customer, and this would also not be efficient because multiple pots and setups would be required in order to keep up with demand.

After talking with the client, and considering the cons of Prototype I it was necessary to rethink the entire idea and consider a totally new solution.



#### Figure 9: Sketches for Prototype II and III

The idea for Prototype II and III is quite different than that of Prototype I. This idea consisted of having bulk containers that would be kept stationary and inside a temperature-controlled room. This is how SPYCE, the inspiration for the entire product, goes about storing ingredients and this was the desired method of storing ingredients by the customer. A temperature controlled room would ensure that the bulk containers are kept sanitary, given that they are all kept in temperatures below the Danger-Zone temperature of 4°C to 60°C. The ingredients would also be kept preserved in the refrigerated room as well. This means that a method of transporting the ingredients from the temperature-controlled room and towards the cooking station would be required from the design. This design differs from Prototype I design in the sense that it incorporates a track system.

The new idea measured ingredients in a new manner. The ingredients will be measured using a weighted measuring device that consists of both weight sensors and trap doors located at the bottom of the bulk container. Once the trap doors open, and the food begins to fall into the ingredient boxes. The sensors located in the bottom of the ingredient boxes will be covered by one uniform material, which will allow the weight of the ingredient to be dispersed and evenly transmitted to the sensor. As the desired mass of the ingredient is reached, the sensor would then trigger the trap doors to close and stop the flow of the ingredient.

At this point, the measured amount of the required ingredient would be in an ingredient box. From here, the ingredient would be transported to the cooking pot by a track system. The track would lead to all of the bulk containers, which would each contain a specific ingredient. The track would lead to all of the individual cooking pots.

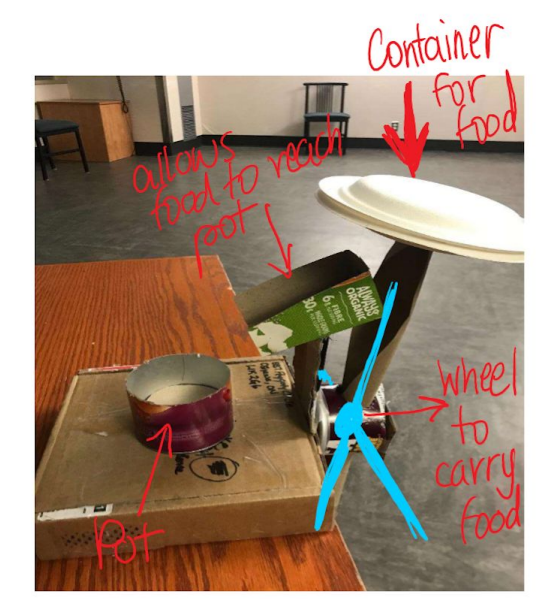
Prototype II, which was the first prototype made to represent this idea, was made of scrap materials. This allowed for exploring the idea and communicating it to others for feedback. Prototype III was made with more detailed materials in mind, as described in the materials section of this report.

Prototype III was obviously not made of the materials that the final product would be made of. The product would ideally be made of stainless steel, which is a food grade material, but would also be environmentally friendly, and easily sanitized. As metal can be recycled many times over, our design would not end up in the landfill at the end of its lifespan. The bulk containers and ingredient boxes could be sanitized using a soapy and boiling water mixture to be cleaned fully.

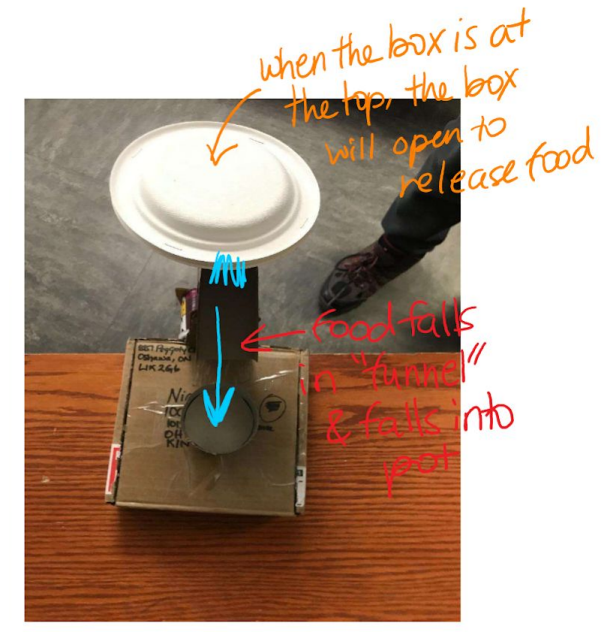
# Prototypes

## Prototype I

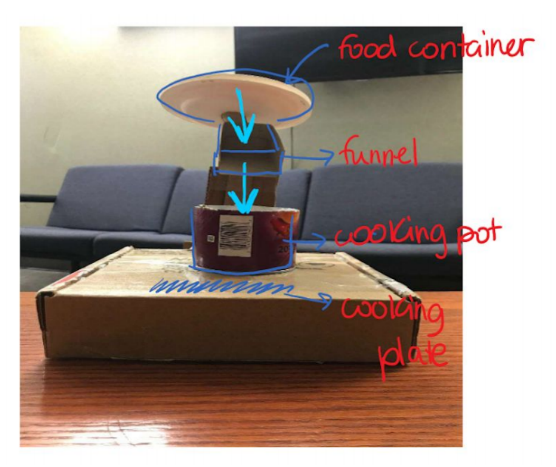
At the stage of the project in which the prototype I deliverable was due, the final idea mentioned in the previous section was chosen to be modelled as a physical prototype. The first prototype for the design was created using scrap materials in order to convey the idea of the design while still maintaining a low budget.



*Figure 10: Prototype I Side View*



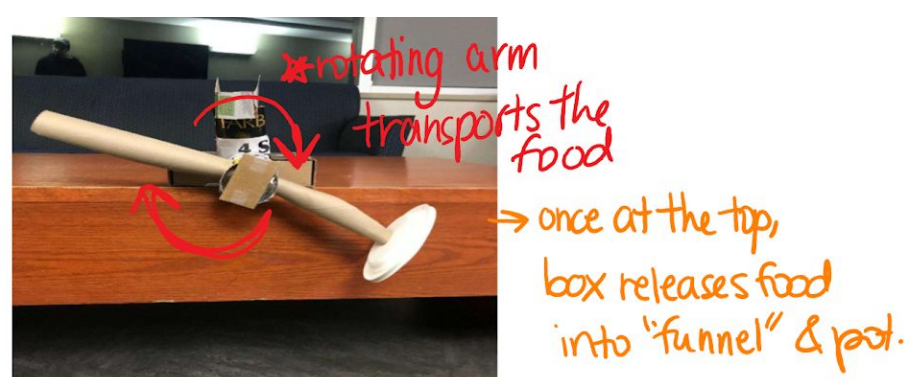
#### Figure 11: Prototype I Top View



#### Figure 12: Prototype I Front View

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#### Figure 13: Prototype I Rotating Arm with no Container Attached



#### Figure 14: Prototype I Rotating Arm with no Container Attached Rotated

Although this design is unique and interesting, it is flawed. This design met many of the requirements that were put in place by the customer, however, it was easy to see that there were also issues with the design. This design relied on time to measure the ingredients, and this is not the ideal measurement system because the flow rate of the specific ingredients inside the bulk containers would change based on how full the bulk container was at the given time. The design was also flawed because the rotating axis would have to support a large amount of weight, given that the customer desired bulk containers that could sustain the restaurant for extended periods of time and this amount of weight would be difficult to support. Each pot in this design would be also stationary, meaning that each bulk setup would have to be specific to each recipe. This would also not be efficient because would be a need for multiple of cooking pots in order to keep up with demand. In the end, it was determined that this concept was flawed in so many aspects of the design that a new idea needed to be established. After discarding all of the ideas that were generated in the initial concept production phase, it was necessary that completely new ideas were considered.

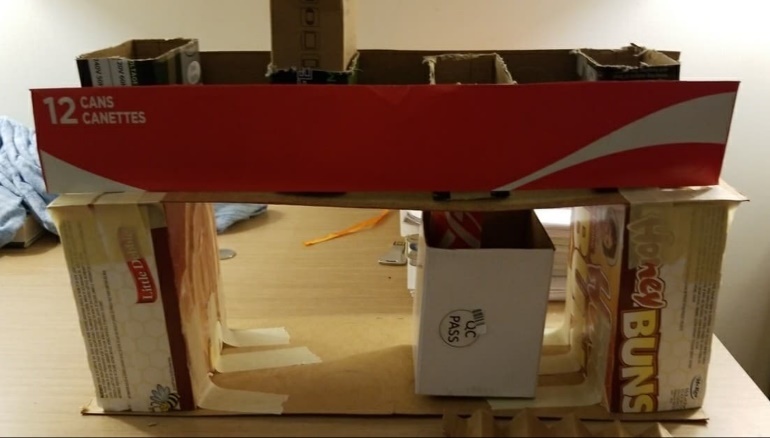
## Prototype II



#### Figure 15: Prototype II Front View



#### Figure 16: Prototype II Top View



#### Figure 17: Prototype II Side View

Prototype II was made of scrap materials because at this point of the design process, the idea was still being refined, and parts had not yet arrived or been ordered in order to create a prototype of actual working materials. The prototype conveys the idea of having stationary bulk containers that would supply a measuring device with the ingredients. The ingredients would travel along a track and into the cooking pot.

## Prototype III



#### Figure 18: Prototype III Side View

Bulk containers feature a tapered design to allow the ingredients to flow out of the container, without getting stuck in corners.



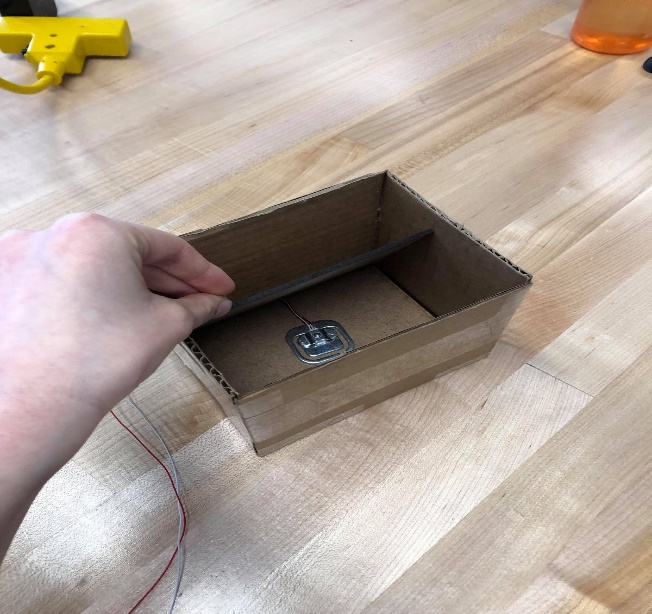
#### Figure 19: Prototype III Top View



#### Figure 20: Prototype III Side View of Motors Controlling Trap Doors



#### Figure 21: Prototype III Side View of Trap Doors Opening



#### Figure 22: Prototype III Revealing Weight Sensor Inside of Ingredient Box



#### Figure 23: Prototype III Weight Sensor of Ingredient Box Covered with MDF

# Project Plan

The project began with deliverable A, which involved forming a team of five and creating a contract that the team should follow for the rest of the term. This involved team procedures, expectations and consequences for failing to follow the procedure and meeting the expectations.

The next deliverable was to determine the client needs and problem statement for the project. At the time the whole class was working with a different client that wanted to analyze tuberculosis through human saliva. There was not much known about the client and the project itself, which made it difficult to formulate any needs and an accurate problem statement.

When it came to deliverable C, the class was assigned a completely different client along with a different project. This project involved designing an automated cooking device that will replace unskilled employees in the food industry that will be cost efficient, safe, time proficient, customizable and consistent when creating food for the customer. This deliverable involved determining the design criteria and target specifications of the project. This can be done by doing benchmarking different products and determining the most important aspects from each product. On top of that, functional and non-functional requirements need to be listed as well as constraints.

The following deliverable was to brainstorm several ideas that would solve the problem statement. Each group member will come up with three ideas and explain how each will function, the advantages, disadvantages and how well it meets the design criteria. Once that was completed, the team will chose the best idea that best meets the design criteria.

Deliverable E was the project plan and cost estimate. The plan would be used as a guide of each task and action for the team for the rest of the term. This was created using spreadsheets and showed the task dependencies as well as who was responsible for the tasks. The cost estimate was a rough approximation of what materials were needed.

Following was deliverable F that involved the prototyping the best idea created from the brainstorming process. This first prototype was created using easily available scrap materials, such as cardboard and paper. It was also needed to create a prototyping test plan that will demonstrate the features of the prototype. This prototype was a very focused and physical prototype that did not have too many working features. The main goal of this prototype was to receive feedback from the customer, but since the customer could not arrive to the meeting, no conclusive feedback was received.

The next deliverable was the same idea as the previous, where it was needed to make a second prototype and test plan. In between the Deliverables F and G, a meeting with the client had been scheduled, this resulted in significant changes in the prototype due to the initial idea being too flawed to work. Therefore another design needed to be created, except there were no more client meetings preceding the previous meeting to receive more feedback. The redesigning started too late due to the late feedback, therefore no testing could be done on the prototype. This prototype was focused and physical which had only a few working parts and was mostly made of cardboard.

Deliverable H concluded prototyping with the third prototype of the project. Losing two group members consequently forced the prototype to be very focused as there was little amount of time left to create the entire idea. It was decided that the measuring and dumping aspect of the design would be the most important to focus on for the rest of the term.

For Design Day, the final prototype did not fulfill the plan that was set for Deliverable H as the measuring aspect did not make it into the design. This happened because the part that would allow the measuring aspect to function would not be delivered until after Design Day. All that could done was to add finishing touches such as paint and parts that would symbolize materials that could not be included.

# Materials

## Material Used

Prototype I and Prototype II were both made of scrap materials, primarily cardboard. In the creation of these prototypes, tape and glue was also used in order to keep the pieces all together. Prototype III used much more complex parts and actually required ordering materials online or shopping in the Maker Store.

To create the bulk containers, the following materials were used:

* 18 by 24 inch, ⅛ inch thick MDF sheets
* 2 by 4 wooden planks, cut, to reinforce structure of boxes.
* Screws
* Wood glue

To create the bulk container stand, the following materials were used:

* 2 by 4 wooden planks
* Screws
* Paint, for finishing touches and aesthetics (not necessary)

To create the bulk container trap doors, the following materials were used:

* 2 Micro Servo Motors
* 1 Arduino Uno Control Board
* Jumper wires
* AA Battery Pack
* USB Adapter
* Screws
* 18 by 24 inch, ¼ inch thick MDF sheets

To create the ingredient boxes, the following materials were used:

* 2 HX711 weight sensors
* Cardboard
* Tape
* Hot glue

Had the parts been ordered in time, the ingredient boxes would have been completed with a few additional parts. These parts include:

* An arduino 400 point breadboard
* A HX711 module
* Arduino Uno Control Board

For display purposes on Design Day, a display track system was created using the following materials:

* Cardboard
* Wooden dowels
* Screws
* Paint and tape as aesthetics

A cooking pot was also used in the Design Day display in order to demonstrate how the track would lead the ingredients directly to the cooking pots.

## Specific Material’s Features

Micro Servo Motors:

The motor has an operating speed of 0.12 second/60°, a torque of 1 kg/cm and an operating voltage of 3 to 7.2 volts. The temperature range of the motor is -30 to 60 degrees and this is valuable for this project because this motor will be able to function inside the temperature controlled room that is desired for the design. The operating voltage of the motor is an important aspect to note as the Arduino is capable of powering one motor meaning the other motor for each set of trap doors would need to be battery powered.

Larger and more powerful motors would need to be used for the real product to support heavier ingredients such as chicken, potatoes, among other ingredients.

HX711 weight sensors:

This specific load sensor has a weight capacity of 50kg, which is more than needed in the case of measuring the ingredients required for this product. The sensor also has a comprehensive error of 0.05 mv/v, an input and output resistance of 1000 ∓ 20 Ω, and an excitation voltage of  ≤ 10 V. The sensor also has a temperature range of 0 - 50 degrees, meaning that it will be compatible with the temperatures that the ingredients will be. This also means that motors will not be affected if they come in close contact with the temperature controlled room or cooking pots.

HX711 module:

This module works to convert analog data to digital data for the Arduino to read. The output of the module would be measured in grams. The module can function in extreme temperatures from -40 to 85 degrees.

# Future Work

There are many things that could be added to the design and to our prototype in the future in order to create an even better product. It would be ideal to have the prototype and product be a full representation of the idea for the solution of the client’s problem. Future plans would involve installing a weight module to precisely measure each ingredient accurately by weight. It would be ideal that when the weight sensor approaches a certain weight, the trap doors would close, shutting of the flow of ingredient and leaving the desired amount of that specific ingredient in the ingredient box. In the future, adding in a working conveyor belt system that would properly, accurately, and in the correct order, transport the ingredient boxes to their corresponding locations, such as the cooking pot and the dishwasher would also be ideal.

There are always many ways that a product can be improved and continuously worked on. The MakerSpace machine could be improved in many ways upon continuing to work on the design, outside of the course’s timeframe.

# Conclusion

Although the prototype created does not necessarily reflect the idea of the problem solution fully, the idea itself is well rounded and meets the interpreted and expressed needs of the customer. The design is safe, with minimal moving parts, which also allows for the product to be easily repaired. Being easily repaired was a desirable factor for the customer because it reduces the chances of the establishment having to be shut down, or cooking being slowed due to breakages and the need for repair.

By utilizing a combination of timed, and weighted measurements, as well as gravity, the measuring device would measure the ingredients to their exact weight. The weight and time system will be accurate as each ingredient’s measuring system would be programmed specifically for it, and in turn, be accurate every time. Since the timing of ingredient dispensing will be on accurate and fast this will reduce wait time for customers, which was another desirable feature for the customer. This design considers and takes into account the space that would be available inside a kitchen. Combining the vertical and horizontal space in the room, this design will utilize both aspects.

By placing the whole prototype inside a temperature controlled room solved the issue revolving around keeping kitchenware clean and the ingredients sanitized in a temperature outside of the danger zone.

The stainless steel design will be easy to clean and sanitize. Not only is this a customer requirement, but it is required by law to have a clean and safe environment in the food industry. This design will abide by these rules. The stainless steel design is also sleek looking and plays into the customers desire for an aesthetically pleasing product, which will leave customers in awe after seeing the process unfold.

This design takes into account the customer’s needs, desires and considers the requirements of the food industry itself.

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