Cocktail Cube

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Abstract

During a bar's busiest nights, the bartender can quickly become overwhelmed from the large number of drinks being ordered. This generally leads to inefficiency resulting in a loss of potential profit including the under-serving of drinks, spilling of ingredients, inaccurate pouring of liquor, unsatisfied customers, and poor company reputation. To address these inefficiencies, Team 2 performed both kansei and conjoint survey analyses to determine customer preference and has prototyped and developed an autonomous cocktail machine to assist the bartender with drink making features including: automated drink mixing/pouring, adjustable concentration knobs, automated self-cleaning, and a 50 drink capacity. After researching the consumer market and demand for the product and performing a cost analysis, APD Team 2 determined to price the Cocktail Cube at $400 per unit. This, coupled with further investment and pro-forma analysis, Team 2 determined it would take approximately 3 years to break-even and after 3 years the company would yield approximately $800K in total revenue and a 25% growth rate. This report describes the entirety of Team 2's design process including design objectives/decisions and why, market analysis, and any assumptions made during the process.

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Nomenclature

Symbol	Definition
a	Average acceleration of a person fast walking (ft/s^2)
C_m	Center of mass
D_X	Distance from origin point to center of mass in x-direction (product width) (ft)
D_Z	Distance from origin point to center of mass in z-direction (product length) (ft)
F_{Actual_force}	Actual applied force onto product from user (lbf)
F_G	Force of gravity (lbf)
F_N	Normal force of the product (lbf)
F_{Push}	Pushing force product can withstand from a person (lbf)
F_S	Static frictional force on a standard wooden surface (lbf)
F_{Tip}	Tipping force product can withstand from a person (lbf)
H	Height of the product (ft)
m	Mass of person/user (lbm)
M	Gravitational weight of the product (lbf)
M_o	Total moment about the origin point O (lbf*ft)
O	An arbitrary origin point to calculate total product moment
T	Time taken to reach average face walking speed (s)
u	Coefficient of friction of a wet wooden surface
v	Velocity of a person while fast walking (ft/s)

Introduction

Let’s imagine a scenario at your local college bar, a favorite among students such as Scorekeeper’s Bar & Grill or Rick’s American Café.

John is standing around a table talking with his friends on an extremely busy night, as most Thursdays-Saturdays are. It is hot in the bar with so many people packed inside, and a cold, delicious beverage is exactly what they need to get the night started. After pushing their way through the crowd and making it to the bar, 10 minutes have passed before John and his friends finally get the attention of the only bartender. John orders four drinks and gives the patron his credit card. The bartender, noticing the crowd building up and only getting more frustrated with the service, continues to get swamped with drink orders. Rushing around to try to keep up, the bartender mishandles glasses while trying to remember all the drink orders as more people continue to pile in. Finally, after another 10 minutes of scrambling, the bartender brings John and his friends their drinks. After trying the drinks, it is clear that some drinks have too much alcohol in them while others seem to have barely any at all. Frustrated and annoyed, John and his friends quickly finish their drinks and head to another bar, leaving no tip as they leave. Many other customers feel the same way as John and his friends and proceed to do the same. In this process the bartender as well as the bar have missed out on tips, profit, and potential future customers.

Based on survey data collected across the campus at the University of Michigan and Ann Arbor, many people felt that popular bars/clubs, especially on college campuses, experience mishandling of drinks and long waits for them while at their local popular bar. Owners of these businesses and also their employees, continue to miss out on potential revenue and tips due to three main factors: under serving their customers, imprecise pouring/spilling of liquor, and loss of future customers due to dissatisfaction. APD Team 2 has taken the task of designing an autonomous cocktail machine to help address these issues to ensure customers receive a well-mixed drink in a timely manner with equal proportions and a zero-spill factor. Our product will assist bartenders and bar owners during busy nights by alleviating the intense workload of the bartender, bringing in more money in tips for the bartender therefore creating more content employees, and lastly producing more money in revenue through drinks sold and returning customers. This report will provide the engineering design process that supports the creation of this product and will demonstrate its realized profit and long-term success. In addition, in-depth business and market analysis will highlight the investment opportunities and encourage support from partners and investment capital firms. Specifically, this report will offer overviews of the design concept, prototype generation, business opportunity, associated financial data, and other supporting documents.

Previous Designs

Like any product, designers and inventors aim to make designs unique in order to increase marketability. Our product is marketed generally toward bar owners but will be used by bartenders and will directly affect customers who frequently attend bars and order cocktails or other beverages as well. To understand the current market in automated beverage machines, we researched similar products and compared their functionality and services.

While the product design is important in pursuing successful implementation, one must also consider the process as a whole. This includes the individuals involved, the environment and ambience, as well as any other external factors such as policy, culture, and circumstance.

Barbotics Cocktail Machine

The Barbotics cocktail machine and robotic bartender can be for both residential and commercial usage. It's affordable if for residential usage, starting at prices as low as $99. For commercial usage, the product can be used in many locations, such as luxury suites, hotels, theaters, nightclubs, casinos and cruise ships. The product can be customizable and have add-ons, such as bottle service, portability, and increased precision. This makes it available for all customers (bartenders or bar patrons), and is designed to provide services for all customers. Also, Barbotics is made for luxury cocktails holding lots of different liquors and juices, and so for commercial use it will need to be refilled regularly. Also, the system has a complex user interface with phone capabilities, making it non ideal for quick bartender use. Depending on how the product is customized and how it's used, it would still require a bartender to deliver the drinks, heightening bartender assistance.

Figure 1A: Shows the barbotics cocktail machine

The Qube Cocktail Machine

The Qube machine is easy to operate and is efficient in making cocktails, without the need of multiple people. The machine is also easily programmable to allow it to make any cocktail for any occasion. The product has full cost control and makes consistent mixed drinks. It also has an aesthetic design and an LED system for it to change colors, which makes it ideal for all places such as hotels, restaurants, trade fairs and bar events. It can make multiple drinks in a short span of time, is easy to clean and is refrigerated to keep the drinks as fresh as possible. It's easy to switch in and out bottles to allow for a variety of drinks to be made. The machine's touch screen can also be customized depending on the experience of the bartender or user (such as displaying more options for drinks or additions to drinks). Overall, the functionalities of this product lessens the need for a bartender, therefore reducing overall bartender assistance, as it can produce drinks for the customer through the touch screen system. However, a bartender would still need to check ID's for each customer.

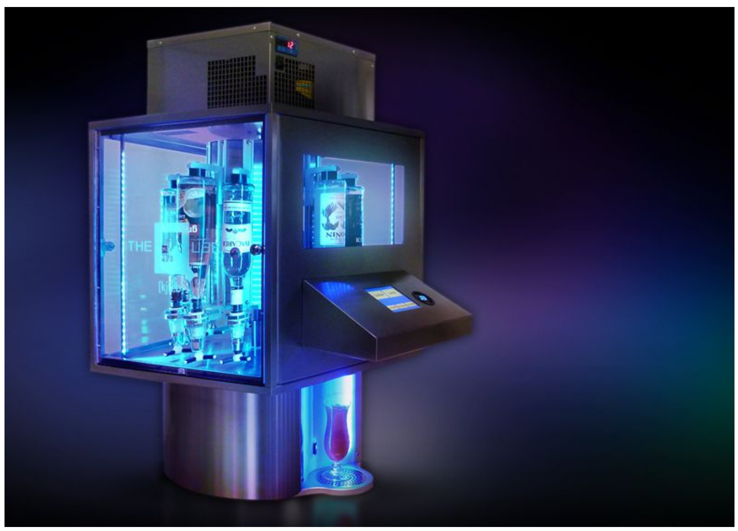

Figure 1B: Shows the Qube cocktail machine

The Inebriator Cocktail Machine

To understand how some of these products are manufactured and what technology is used, we found a product that listed both the electrical components and features. The Inebriator machine is programmed using an arduino mega 2560 microprocessor project board which is the main source electronics prototyping platform. The machine also has a separate console which is composed of a Fez Panda II and rotary encoder. These two components allow the users to select a drink from the menu, and the information from commands is sent to the arduino. A stepper motor runs the drinks drive at various speeds and accelerations to make sure it doesn't spill. All the mixers are controllable and are composed of plastic bottles, piping connected to gas tanks and valves, and pressure regulators. There's a force sensitive resistor to ensure glass doesn't become broken (if there's a glass in the way of another being poured). The machine also integrates a RFID sensor, which utilizes RFID tokens to prevent people from ordering an excess number of drinks. The machine also has numerous LEDs that allow the customers to see the drink being delivered and for aesthetic purposes. The Inebriator is easy to use, and utilizes technology that is feasible for our product. Since the purpose of the product is to similarly produce drinks at a faster rate for bartenders, it provides higher bartender assistance, but could potentially mitigate the need for a bartender.

Figure 1C: The Inebriator

Monsieur Robotic Bartender

The Monsieur can make a variety of drinks from a combination of 8 ingredients, which are based on a theme.   From each theme, approximately 30 cocktails can be made, each displayed on a touch screen with information about the drink. The machine is also compatible with RFID to allow mobile payments and age verification of customers. The product also is provided with bottle adaptors, so each ingredient can be dispensed directly from the bottle. Monsieur is overall easy to use and easy to clean, as it has an on-screen tutorial with instructions on how to clean the product, which only takes minutes to clean. Because the product uses mobile payments, a touch screen for ordering drinks, and mobile age verification, a bartender isn't necessary, except for replacing empty bottles. It also doesn't account for the possibility of an underage person using another patron's ID to illegally order a drink. Because of this product's features, it would potentially eliminate a bartenders job rather than provide assistance.

Figure 1D: Shows the Monsieur Robotic Bartender machine

Smart Bar USA Smartender

This product can make a multitude of drinks, with approximately 600 drink options. It also has easy managerial and customer software for navigation, changing drink options, and easy screen display customization based on customer needs. The product can come as both a portable and modular system. The portable system has a dispenser head which eliminates over-pours, a card reader for age verification, bins for garnishes and ice, and a drawer for holding bottles. The modular system has the same features except it can also connect to the city water and has a pump system included. The product's outer design also be customized with different finishes. Overall, the product can be applicable for many events. Similar to the Monsieur, it uses a touch screen and a card reader for ordering drinks and age verification. It also doesn't account for underage customers using fake or other people's ID's to illegally order drinks. With the previous stated features, this product makes having a bartender unnecessary, which would potentially eliminate a bartenders job rather than provide assistance.

Figure 1E: Shows the Smart Bar USA Bartender machine

Conclusion

Overall, after talking to various bartenders of local popular bars and customers who visit them, it is clear that people from both groups believe the process can be improved. Customers had complaints about waiting excessive amounts of time for drinks, and bartenders expressed interest in a product that could help them handle the overwhelming workload during the bar's busiest nights. When looking at past designs, most of these previous products intend to eliminate the need for a bartender. After interviewing local bartenders, we found most of them disagree with these products due to the feeling that they virtually replace their jobs despite the legal ramifications of introducing such a product. Because of this, our product aims to work with the bartender to alleviate the strenuous workload while facilitating an increase in productivity. The product will be simplistic and automated, but rather than acting as a secondary bartender, it will effectively accelerate the bartender's tasks, acting as an extension of the bartender. Whether the drinks are being made behind the bar or at another location within the room, the bartender will have control over which drinks the machine is making, how much alcohol and chaser are being mixed into the drink, and how many drinks are being served to each individual all while maintaining social interactions with the customer. This, in turn, sets our design apart from these past designs. By designing with the viewpoint of both the people purchasing the drinks and the bartender, we have created a design that makes the bar experience better for all parties. This will, in turn, help the bartender work more quickly and efficiently, help the customers get their drinks faster therefore giving them more time to dance or talk with others, and lastly, bring in more profit to the bar owners themselves.

After additional field research, catering companies were identified as an additional application for market segmentation. During most catering events, the drinks being served are fairly simple and part of a short menu of options to be delivered to a large quantity of people. With a machine that automates pouring, mixing, and contains from 2-4 ingredients that incrementally dispenses the necessary liquid portions to a cocktail, productivity can increase substantially. This opportunity could present an additional market segment and business model as opposed to strictly commercial use. Instead of only paying retail price for the machine, rental or leasing options could be considered reducing the reliance of customer required maintenance.

Design Objectives and Requirements

To better understand our market and what people expect in an autonomous bar machine, we conducted two surveys, namely a problem definition survey and a conjoint survey. Because there are previous designs similar to our product that already exist, we started thinking about attributes that would make our product more desirable and set it apart from the others. Since we are focusing on bartenders and waitstaff to be the actual users of our machine, we gathered information from local bars and restaurants about their preferences relating to an autonomous cocktail machine to assist them with their work. From these interviews, we developed the list of attributes below.

Ease of Use

The primary purpose of this product is to save the time of employees by automating the process of mixing drinks and allow them to perform additional tasks such as taking more orders or carrying out charges while the machine makes the drinks for them. While it is important to have functionality, it is often difficult to design something that is easy to use but also customizable. The key in this design will be to allow a simplistic interface but still provide the functionality, accuracy, and precision of pouring. Because of this, we used buttons and knobs rather than a touch screen and confirmed this desired attribute through kansei survey and analysis. The intended purpose or our device is for mixing and dispensing, while everything else is still done by the bartender, so these features will allow them to do their job quickly. The product should be easy to use without much training.

Speed

Product functionality needs to be quick in nature, the user should be able to use this machine to make drinks faster than without it. Our product will speed up the drink distribution process.

Maintenance

The product shall require low customer maintenance or the opportunity to have maintenance provided by our company. The purpose of this is to allow for bar owners, bartenders, and also customers to not need to worry about the state of our machine and to not have to spend long periods of time cleaning or repairing the machine.

Versatility

The product will be able to complete multiple tasks regarding our problem statement. This will make it more useful to our consumers.

Security

It is important that the proprietary software or hardware can not be disrupted to result in undesirable outcomes neither by customers able to extract information from the machine without ownership nor users with intention to cause the machine to malfunction and bypass any verifications.

Portability

The product should be minimized in size, to allow for easy implementation into bar or restaurant settings. They should also be easy to transport when needing to move product from venue to venue.

Affordability

The product shall be set at a price that makes it affordable for our intended consumers. This device needs to be able to give them investment returns shortly after their purchase.

Ease of Installation
Since the product will have multiple end users, such as bartenders and catering companies, it needs to be easy to install when being moved from place to place.

Aesthetics
The product needs to be aesthetically pleasing to fit into the desired environment. It needs to be expressed as an extension of the bartenders ability to make drinks more efficiently, rather than a machine that eliminates the bartender.

Durability
The product is an additional appliance for bars and catering events, and therefore needs to be durable enough to withstand movement, spills, rust and long term use.

Attribute	Importance			Characteristics				
		Steps to Use	Size	Weight	Strength	Cost	Number of Parts	Dispensing Time
Ease of Use	5	5					4	3
Speed	4	4					4	4
Maintenance	4	4	4				3	
Versatility	4	4			2		2	
Security	3							
Portability	2		2	2			3	
Affordability	2					2	2	
Ease of Installation	2		2	2				
Aesthetics	2		2	2				
Durability	2		2	2	2		2	

Figure 2: A design mapping matrix that translates our design attributes to measurable characteristics. It's important for our product to take into consideration steps to use, size, weight, number of parts, cost, and dispensing time.

The characteristics shown in the above figure will be used to define the success of our product. These characteristics can be quantified into objectives and requirements, which have maximum and minimum target values that either must be satisfied or will aim to be satisfied . These values will determine the successfulness of our design.

Objectives Derived from Characteristics

Steps to Use
The process to which we want consumers to make a drink is very important to us. We aim to have the fewest operational steps possible so customers experience small wait times when getting a drink. As the design of the device continues, the amount of steps needed can change therefore this characteristic is labeled simply as an objective. Targeted values for this objective are low, owing to the fact that we want the minimum number of steps required to make a drink. The objective will be measured by physical interactions with the machine from the users i.e. bartenders. For now, the objective will be to have a maximum of 3-4 interactions including

loading glasses into product, manipulating ingredient concentrations, and finally dispensing the drink.

Size and Weight

The size and weight of our device is contingent on future design of the product. The target is to minimize volume and surface area (number of cubic inches) to allow for ease of use, manufacturability, transportation and maintenance while still maintaining feasible features. Size and weight will be compared to existing products to determine acceptable parameters. For now we are planning on creating a product that has a weight of 29 lbs before the loading of drinks with 20.5''x 21''x 18'' dimensions.

Number of Parts

The product we are creating will be focused around an electro-mechanical system. Therefore, we need to assure it will be easy to manufacture and repair. For now, we are planning to incorporate a user interface, appropriate firmware, pumps, containers and an outer shell that will house all of the components. We want to reduce this number as much as possible, aiming for a finalized part list to be under 25 parts.

Strength

This product is intended to be used in particularly busy nightclubs/bars and catering events. Because of this, we need to assure it can withstand rough contact or any unintentional forces. The engineering analysis better explains our reasoning . We plan to make a product with a minimum tipping force of 18-26 lb force to tip the product over.

Requirements Derived from Characteristics

Cost

This is an important requirement to our product because we want the product to be seen as an investment to our customers. Thus, they'll need to see returns on the product early in the products lifetime. After doing a conjoint survey and profit maximization analysis, we found that price of the product is not the most important feature, therefore we aimed for our product to cost around $400. Currently the total cost to make the product is $300 resulting in a $100 profit for each product sold. Any additional maintenance costs will be covered under warranty by us for under $50. This insurance will increase customer comfort and confidence during their purchase.

Dispensing Time

Dispensing time was determined to be one of the most important requirements. To assure that the machine can work more efficiently than a bartender alone, the machine has a dispensing time of approximately 13 seconds from when ingredient ratios are set to when the drink is finally dispensed and ready to be served.

Table 1: A chart categorizing the design characteristics into objectives or requirements and showing the target or minimum/maximum value determined for each characteristic

Design Characteristic	Objective or Requirement	Min/Max or Target Value	Measuring Method
Steps to Use	Objective	Min	Physical Actions
Size	Objective	Min	Inches
Weight	Objective	Min	Pounds
Strength	Objective	Max	Stress/Strain
Cost	Requirement	Min	Monetary
Number of Parts	Objective	Min	Count
Dispensing Time	Requirement	Target	Minutes

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Concept Generation and Selection

After defining our desired attributes and characteristics, we started to look at different models that could embody these traits. We collected data from two separate conjoint surveys given to our class and also personal talks with bartenders and waitresses. Based on these results, several concepts were generated that reflected customers preferences towards these products. We then analyzed these concepts with other bartenders and waitresses. Afterward, we investigated product features that would embody our characteristics and attributes, and then created multiple combinations that would assist our end users. Main traits to the product that we investigated included the number of ingredients each concept could hold, the number of drinks it could produce before requiring a refill, price, size, and which features it would utilize. We also generated concepts that were not directly related to drink creation, due to insight we gathered from servers that indicated there was more to serving drinks than just making them. The list of these concepts are as follows:

Concept 1

This concept can hold a maximum of six ingredients, can produce thirty drinks before a refill of ingredients is needed, design is semi-simplistic, medium weight, and utilizes an automatic drink dispensing system. Since the design is small in size compared to most products and lighter than products such as the Qube, it's easily portable. This concept taught us the benefits of a smaller more portable device and showed us the limits to its storage and electronics capabilities as well. In this concept played around with different types of user interfaces as well, and found that the simpler the UX was, the easier it would be to learn how to use and the less likely it would be damaged. Also the smaller the device is the faster we can make drinks, as there is less distance the liquid has to travel. The downsides to this concept is that the amount of maintenance needed would be more than the other generated concepts, since the pressure compressor and tubes would be difficult to clean. The ice dispenser, mixer and dispensing nozzles would also be difficult to clean. Also, it would need to be refilled frequently throughout the night at a busy bar or party in order to be keep up with large quantities of drink orders. When looking at our survey results and analysis, we found that a device with this size, features, and user interface would cost around $300.

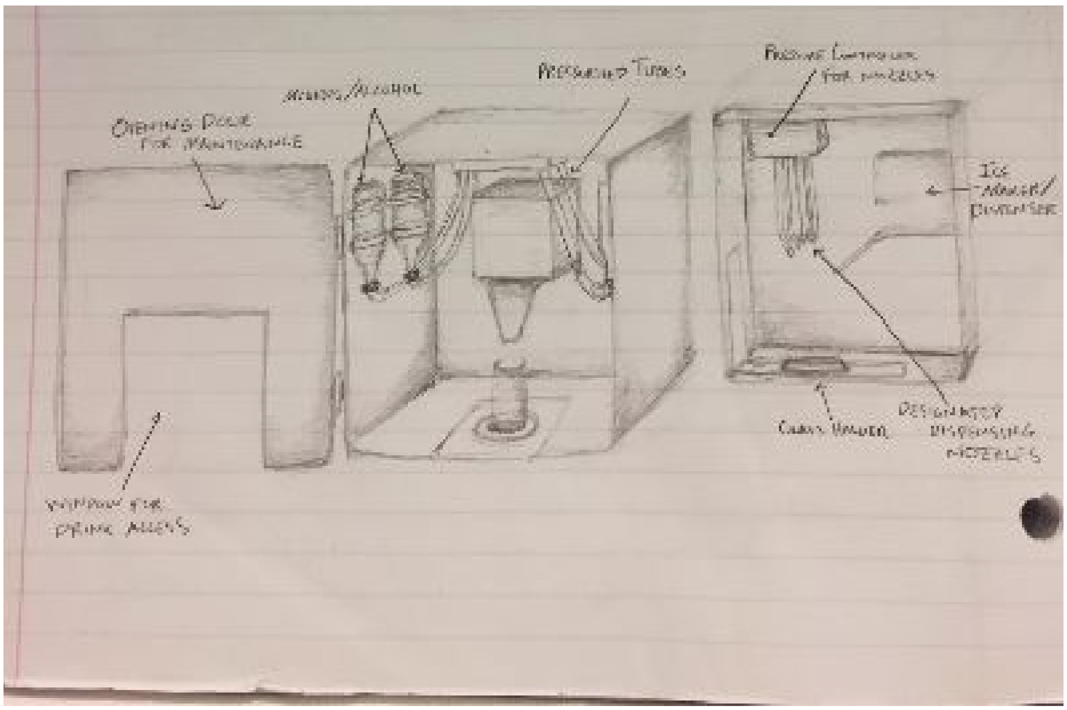

Figure 3A: shows concept 1 and its ability to make drinks, the size would be that close to a microwave

Concept 2
This concept is more simplistic and easier to use. This concept can hold only 2 ingredients, has two dials on the outside to control the amount and speed at which each ingredient enters the drink, and has a sensor to prevent any over-pouring. This concept attempts to align with one of the most popular product choices from the conjoint survey results: it is designed to make one specific drink quickly and consistently. It would be best positioned in a target market requiring little variety with simple, single-push button initiation. Benefits to this concept are its simplistic and lightweight design including the small number of steps required to operate it, its ease of use, portability, and affordability. This concept also has no complicated components, such as a pressure compressor and ice maker/dispenser, easing the amount of necessary maintenance. Lastly, for this product to be effective it would need to be smaller than Concept 1, and thus wouldn't be able to store many ingredients at all.

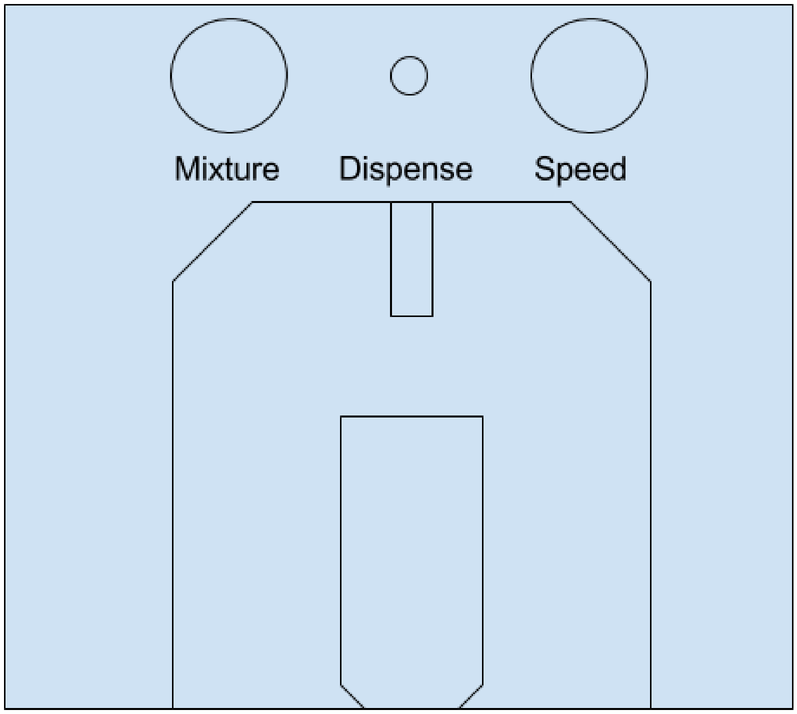

Figure 3B: shows concept 2 with dials that represent the concentration of the two ingredients and the speed needing to be dispensed at. There is a button for dispensing once the inputs have been set.

Concept 3

This concept was the most complicated, but addressed the second most popular product characteristics from our conjoint surveys given to the class including: a lower production rate, with a larger sized product (similar to that of a small oven), more ingredients being held, and more drinks that can be made. A benefit to this design includes larger combinations of drinks making capabilities with more storage for each ingredient to allow for less refilling on busy nights. This design also preffered a more advanced user interface to company the larger array of drinks that can be made i.e. a touch screen interface with wifi connectability. Downsides to this concept were mainly its large size, making it non-portable and more desirable for permanent bar use and not probable for catering use. This concept also possesses more features and aesthetics making it more expensive. All in all, this product would sell upwards of $1000 and would most likely result in higher maintenance fees.

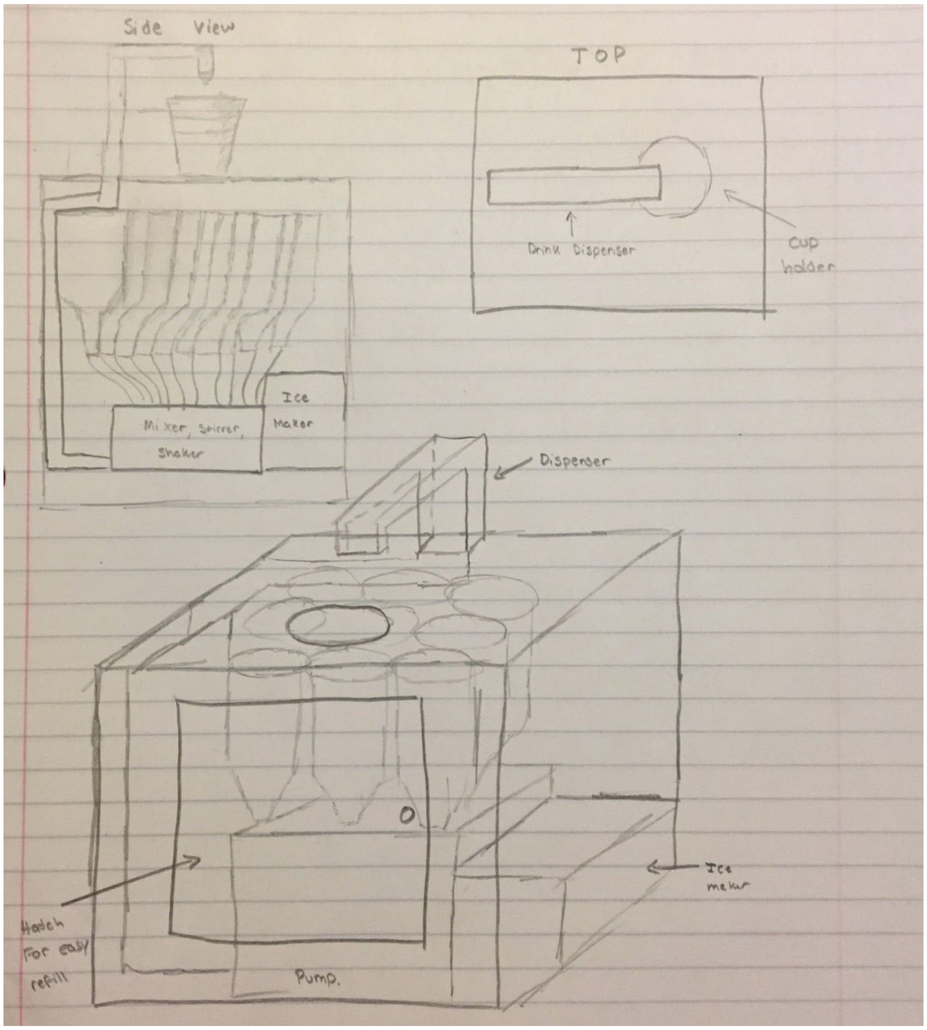

Figure 3C: Concept 3: having a larger design, dispensing spout, and a more complex user interface.

Concept 4

After meeting with our respective GSI's, professors, and some additional bartenders, we decided it best to analyze methods to solving our problem that didn't surround a drink making product. One concept idea generated came from a meeting with one of the bartenders in our research. She mentioned having trouble finding all the ingredients on a busy night. Concept 4 is an electronic lighting system that would point to the necessary ingredients after the bartender input a drink into a computer. This would allow for the bartenders to find all the necessary ingredients for a drink quickly and efficiently. Since this concept was generated after our initial survey designs, we had to ask other bartenders how they would feel about this idea. The feedback received told us that the system would only be useful for new bartenders and that experienced bartenders know where all of their ingredients are. Furthermore, in bars we are targeting (ie. Ricks), the bartenders would find it more distracting to have lights pointing to ingredients when there are often 2 or 3 bartenders on a busy night. Additionally, production of such an electronic system would need to be catered to all different sized bars, with a multitude of different organization methods. Hence, a system doesn't hold enough evidence to consistently solve our problem.

Concept 5
Another concept we developed after talking with bartenders was a drink mixer. This would be a small machine that would mix, shake or stir customers drinks while the bartender was performing other tasks. Again, this concept was created after our surveys were taken, so we had to approach bartenders on campus to better understand how this product would fit into their routine. Feedback came back negative again, in that bartenders would still be doing the time consuming work, and still need to empty/clean any device that is mixing drinks. Additionally, consumers of shaken, fancier drinks preferred to have the bartender do it, because they gained value watching the bartender perform their craft for a fancier cocktail.

Previous Prototypes

We built two prototypes to demonstrate our project idea and the basic functionalities of the product. First, we developed an Alpha Prototype to demonstrate and test the functionalities desired for our final product and get a basic understanding of components and how they would fit together in a device. After doing so, we developed Beta and Beta Plus Prototypes with basic functionalities, such as pumping and dispensing different ingredients, mixing in a chamber, and an electronic user interface that could control the drinks to demonstrate the functionality of our product. The Beta prototype was made out of wood which was stained, fitting the aesthetics found in our surveys. The electronics system was controlled using an Arduino, which took inputs from potentiometers and buttons (ie. user interface) and sent signals to small pumps to dispense the drink. The whole system was powered by 12 volt batteries, however, in the future it will be able to plug into a wall. We have created a virtual final prototype shown in CAD files which can be seen in Appendix F.

For our final product, we are planning to expand further from the Beta and Beta-Plus Prototypes. We want to be able to store at least 8L of liquid, and dispense 50 drinks before needing to be refilled. The user interface will be simple, using buttons, knobs, and lights to denote the ingredient concentrations and when the ingredients need to be refilled as well. We made this decision based on our own user results from our prototypes, where we increased the amount of ingredients held and played around with dispensing times. Using the user interface, we found that the simpler the better. A simple robust system can increase the speed that drinks are made. The next steps include finalizing both a parts list and manufacturing plans for the final production of the product as well.

Product Description

We intend the Cocktail Cube to be a product that will revolutionize bars, clubs, and catering services. Our product allows for bartenders and waitstaff to serve drinks in a fraction of the time.

We have invented a small, portable drink making device that with a 50 drink capacity before needing a refill. We envision our device to be an in-bar product, specialized for commercial use rather than home use. Therefore, we've catered our user interface, refill system, and dispense system for in-bar use.

The early stages of the cocktail cube came about from sketches in *think tank* style idea sessions, where members of the company drew up possible designs to fit our problem statement. These can be shown in Appendix F. The basic mechanics of the system include 8 ingredient tanks that store ingredients to the users choice. If the user wants to store gin, tonic water, rum and vodka as the only 4 ingredients then they have the capability to do so. The idea is that they will choose ingredients that make drinks special to their bar. For example: Rick's, a very popular bar at the University of Michigan is famous for a drink called the "Mind Probe" which contains rum, tequila, Triple Sec, gin, and Sprite. Hence, they would use these ingredients in their machine to make this specialty cocktail quick and consistently. The ingredient chambers are shown in the figure below.


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Figure 4A: The final CAD product, storing 8-1 L containers, and our user interface.

The user interface was designed to be simple and easy to learn, thus taking minimal training to understand. The figure above shows 8 red knobs that correspond to concentration controls for each drink holding container. The top row corresponds to the back row of ingredients, and the bottom row corresponds to the front row of ingredients. We chose this setup to allow for versatility among bars, thus each bar can calibrate their machine to drinks unique to them, their geographic region, or the specialty of the night. The knobs control the concentration of alcohol in each drink through potentiometers, with numbers on the knobs ranging from 1-10 corresponding to percentages in each drink. For example, if a knob is turned all the way to 10 and nothing else is turned, then the machine will fill the drink to the top with that one ingredient. There are two built in features that ensure there is no overflowing. The first is automatic, and uses two sensors to detect first how tall a glass is and then how much liquid is being poured in. The system works with almost perfect accuracy and can account for ice being added to the cup before filling. The second method is with the button. For example, if the user does not wish to fill the glass all the way to the top with a liquid, then they can press the button a second time to stop the flow. Additionally, there are green and red lights on the user interface of each knob to show when the drink cartridges are running low.

The overall electronics system is stored right behind the user interface, and utilizes a programmable microcontroller. The controller connects the knobs and button on the user interface to a series of pumps underneath the containers. Once all the concentrations are set and the dispense button is pushed, the microcontroller sends signals to the ingredient cartridges and pumps the desired amount of each liquid into a chamber below it. This chamber is for mixing the ingredients together then dispensing the final cocktail into the customers drink. A diagram showing the positioning of pumps and the mixing chamber are shown below. With the current technology in our Beta-Plus prototype, we are able to dispense a drink from start to finish in 13 seconds. With more specialized hardware, we aim to get this number below 10 seconds.

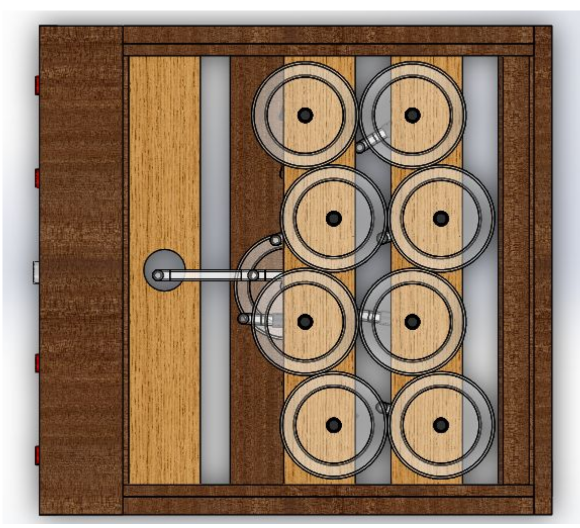


Figure 4B: A top view of the two rows in relation to the front. The electronics is in the space behind the user interface

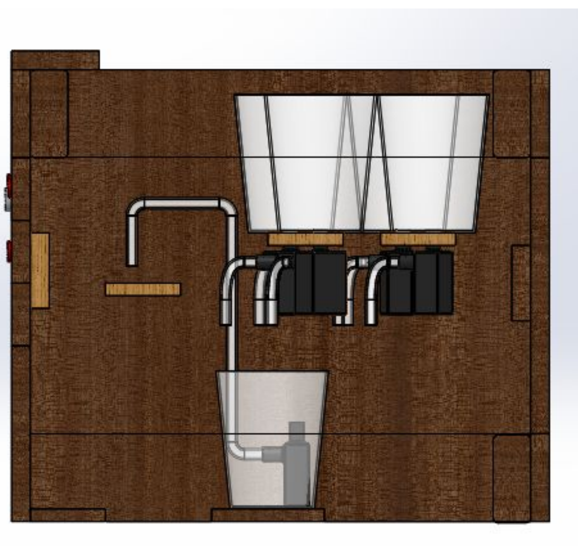


Figure 4C: A side cut, revealing the interconnections of the machine.

Finally, one of the most important features is the cleaning ability. The final commercial product will have a tube connected the main waterline allowing it to rinse the mixing chamber every time the ingredients are changed dramatically. For example, when changing the strength of a drink, the cleaning mechanism will not activate. However, when switching from a Long Island to a Mojito, it will quickly rinse out the mixing chamber and dispensing tube leading to the customers drink. This will cut down on cleaning and maintenance costs and also allows for consistent tasting drinks.

Engineering Functionality Analysis

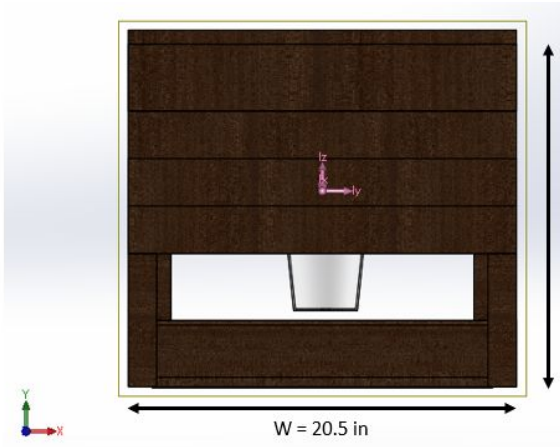
From our Beta Prototype, we finalized our list of materials and the features for our final product. After completing the construction of our final prototype, and composing a list of materials used, we were able to measure the weight of the Beta Prototype to gauge whether it could be easily tipped or moved. We also finalized the electronics used for our product to function and dispense drinks. To ensure our final product was as consumer friendly as possible, we conducted the following engineering analysis to ensure our product was optimally produced and had the best features with the technology at hand.

Product Statics and Dynamics

In most bars or restaurants, cocktail machines are generally kept in a static position for the entirety of the night, and moved only for storage or a more convenient placement. This makes weight rarely an inconvenience to consumers. Therefore, we decided portability wasn't important comparatively to the other attributes. However, these products are exposed to the high paced environments in bars and restaurants, where the bartenders or caterers are constantly moving and possibly bumping into objects. Therefore, we conducted statics and dynamics analysis to ensure our product couldn't easily be tipped or pushed. We aimed for our product to be as sturdy as possible.

Tipping Analysis

To conduct our tipping analysis, we first used Solidworks to determine the products center of mass and weight, which were measured to be <11.33''i, 10.8''j, 16.81''k> and 29 lbs respectively (the "i" direction being along the product width, the "j" direction being along the product height, and the "k" direction being along the product length). This can be seen in Figure 5A-B on page 21. After doing so, we drew a series of free body diagrams and determined where each force (force of gravity and tipping force from a person) would be located and the least amount of force necessary to tip our product (Figure 5C-D, page 21). Below are some diagrams and set of equations to illustrate our tipping analysis. We conducted tipping analysis from two different side views, along the width and length of the product respectively.



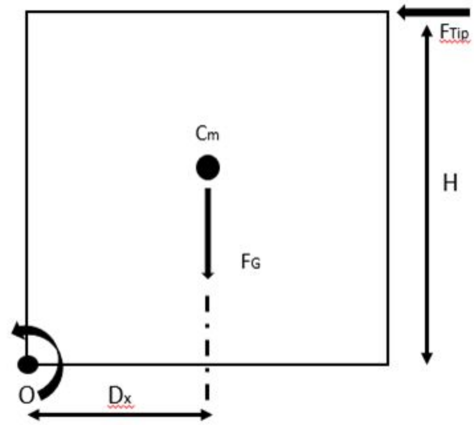
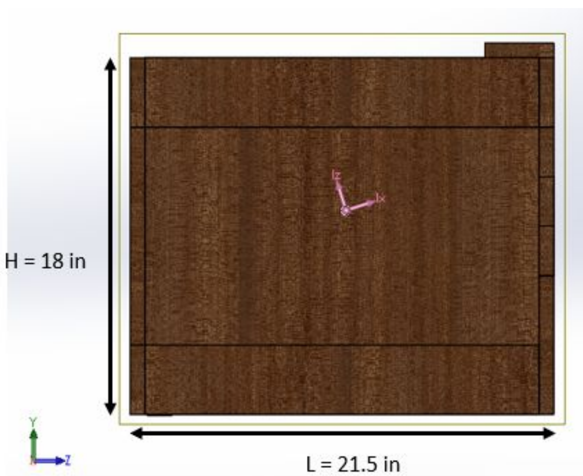


Figure 5A: View of 3D CAD model of final product from X-Y plane side
Figure 5B: Free body diagram of the X-Y plane view of final product for tipping force analysis



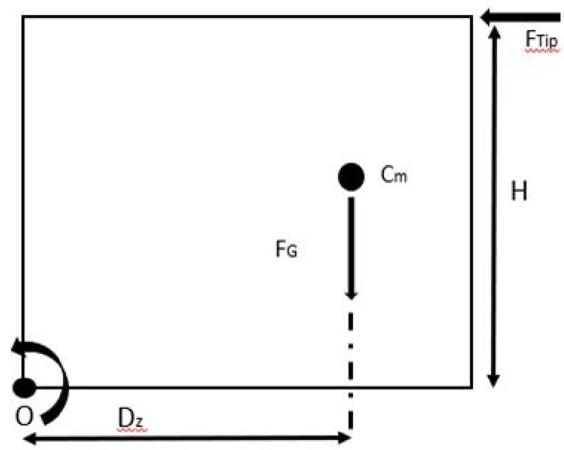


Figure 5C: View of 3D CAD model of final product from Y-Z plane side
Figure 5D: Free body diagram of the Y-Z plane view of final product for tipping force analysis

D_X is the distance from an origin point to the center of mass in the x-direction in feet (direction along the width of the product), D_Z is the distance from an origin point to the center of mass in the z-direction in feet (direction along the length of the product), C_m is the center of mass, F_G is the force of gravity in lbfs, H is the height of the product in feet, O is an arbitrary origin point, and F_{Tip} is the maximum force without product tipping in lbfs. In determining the tipping force, we used the following equations:

$$F_G = M \qquad \text{(Eq. 1)}$$

$$M_o = 0 = (F_G \times D_x) - (F_{Tip} \times H) \qquad \text{(Eq. 2)}$$

where M is the gravitational weight of the product in lbfs, and M_o is the total moment about the origin point O. We analyzed the tipping force from two sides of the product. Using these equations, we determined the minimum sustainable tipping force to be between 18 to 26 lbfs, dependent on the location of the tipping force on the product.

To verify if the product could sustain such a force, we analyzed the mechanics of a bartender and how much force would be applied by accidentally bumping into the product. We first made a number of assumptions about the mechanics of the bartender. We assumed that the bartender would hurriedly be taking multiple orders or cleaning, therefore be fast walking. Therefore, we calculated the average applied force from a bartender while fast walking. We assumed the bartender would have accumulated a fast walking speed of 1.5 ft/s in a period of 3 seconds [3]. We then calculated the average acceleration, using the following equation.

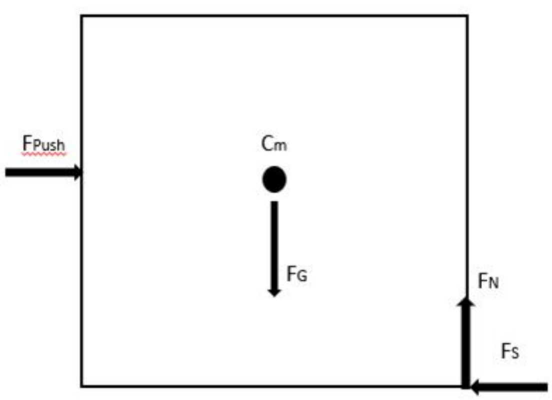
$$a=v/t \qquad \text{(Eq. 3)}$$

$$F_{Actual\_force} = m*a \qquad \text{(Eq. 4)}$$

where a is the average acceleration of the bartender, v is the fast walking speed of the bartender, t is the time passed before bumping into final product, m is the mass of the bartender, and F_{Actual_force} is the force from the bartender walking into the product. From the equation, we calculated the average acceleration of the bartender, from where she collected the drink order to the machine, to be approximately .383 ft/s^2, with the force of the bartender to be approximately 11.83 lbfs. From this analysis, we concluded the product can sustain this force without tipping.

Pushing Analysis

Our pushing analysis was conducted similarly to the tipping analysis, except that the center of mass was not necessary to calculate the pushing force. To reiterate, we weighed the product to be approximately 29 lbs. We drew a series of free body diagrams from two different side views and determined where each force, such as the pushing force, would be most commonly centralized. Below are some diagrams and a set of equations to illustrate our pushing analysis.



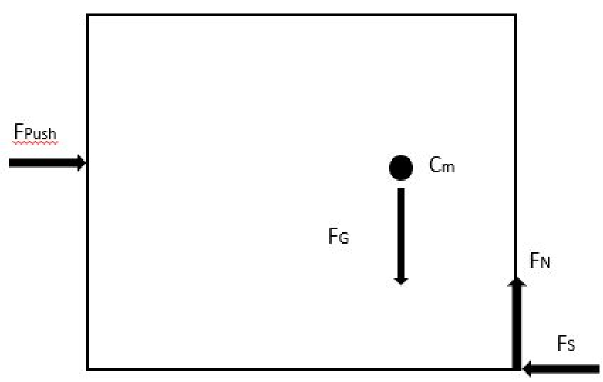


Figure 6A: Free body diagram of the X-Y plane view for pushing force analysis
Figure 6B: Free body diagram of the Y-Z plane view for pushing force analysis

where F_{Push} is the maximum pushing force from a person without product movement, F_S is the static frictional force on a standard wooden surface, and F_N is the normal force of the product. F_G is still the same gravitational force determined from the tipping force (page 21). To determine the necessary pushing force to move the product from a static position, we used the free body diagrams (Figures 6A-B, page 22) and the following equations:

$$F_N - F_G = 0 \quad \text{(Eq. 5)}$$

$$F_S = u * F_N \quad \text{(Eq. 6)}$$

$$F_{Push} - F_S = 0 \quad \text{(Eq. 7)}$$

where u is the coefficient of friction between a wooden surface. Based on these equations and diagrams, the necessary pushing force to move our product would be equal to the static frictional force of the product. Therefore, the maximum pushing force the product could sustain without moving was calculated to be 5.8 lbfs.

We conducted the same analysis on the mechanics of the bartender to determine if the product could be moved. The force from a person walking fast was calculated to be more than the product's static frictional force. Therefore, we concluded that the product could be moved, with the assumption that this force was directly into the product. But because most of these products will be located on a counter space distanced far enough to avoid direct impact, and that most bartenders will slow down to lessen the impact if walking directly towards the product, we determined this to be trivial to account for comparatively to other analyses.

Based on our engineering analysis and assumptions, we concluded that our product would be structurally suitable in a bar environment. Given the calculated pushing and tipping force, it would be difficult for the product to be pushed or tipped off a counter space.

Electronics Analysis

Our product uses a multitude of electrical components to dispense a combination of drinks. Each component is crucial to our product's functionality i.e. for each drink to be dispensed with precision and accuracy. We analyzed the specifics of the electronics and designed them accordingly to increase the safety and ease of use.This section details our products electronics in relation to the design choices behind them.

Our product dispenses drinks, which could potentially spill and leak. Any liquid onto open wires or metal components in the electronics would act as a safety hazard, causing electrical shortages and electrocution of the user. To counteract this occurring, the final product is designed for electronics with metallic components to be protected with a plastic covering. As a secondary safety measure, the wires and electronics will also be isolated from sections holding liquid.

To reiterate from the product description, the machine consists of several ingredient containers feeding into a central mixing container, which subsequently feeds into a drinking glass. Each container, including the central mixing container, has a connected pump and valve, which pumps ingredients to minimize overall dispensing time. Each pump is provided 12V from two battery packs installed within the unit to increase their effectiveness (Appendix C).

To control how much of each ingredient is dispensed into the central mixing container, our product utilizes a knob and button system, which is located on the front side of the product. In relation to the user interface, the knobs are wired to the pumps. These knobs have 10 labeled dispense settings, which adjust how much of each ingredient is pumped into the central mixing container. The settings of the knobs correspond to the percentage of each ingredient into the main mixing container. After adjusting each knob, there is a dispense button in the center, which when pressed, programs the pumps from the user interface to begin dispensing ingredients into the mixing container and then into the drinking glass respectively.

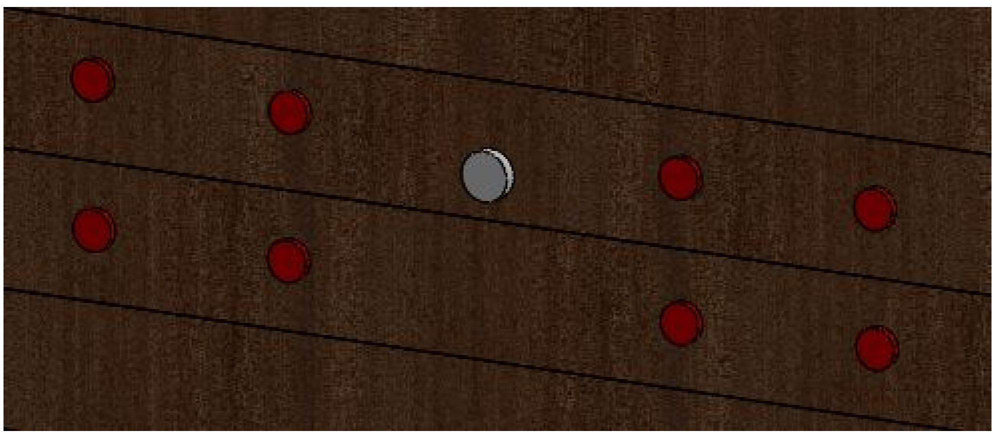


Figure 7: Knob and Button system used in final product

Most environments these products are placed in have dimmed or almost no lighting, making it difficult to see. Without lighting, there would be no indication of where to place a drink glass. To reduce this issue, our machine has an LED system which illuminates the location of where a drinking glass should be placed under the dispensing nozzle. Once the drinking glass is placed in the area, the illumination color changes. Once the dispensing process is complete, the LED system also serves as an aesthetic display for the finished drink and allows the customer to easily acquire it in a darkened environment.

Changes from our Beta Prototype

When our team was designing a product with gravity fed ingredients, we used a design optimization model to maximize flow-rate, with the variable being the height of the containers, the parameters being the area of the nozzles and gravitational constant, and constraints being the height between the top of the liquid in the container and dispensing nozzle. We used a simple expression of the Bernoulli equation to help us calculate the optimal flow rate from the dispensing nozzle. However, once the pumps were installed to each ingredient container, the flow rates were adjustable, eliminating the need to position the containers at a certain height to account for an optimal flow rate. This will also allow for either larger ingredient containers or a smaller form factor dependent on further research and engineering analysis.

Emotional and Aesthetic Analysis

We performed a kansei analysis by surveying people's feelings about different design concepts. In the survey, we decided to propose two perception scales, namely simple-complex and very aesthetic-not very aesthetic and wanted to investigate the effect of four corresponding characteristics (two different levels each) on the perception of each design. Each characteristic and its respective levels are listed below.

Table 2: Design Characteristics and Levels

Characteristics:	*Size*	*Variety of Drinks*	*Drink Selection*	*Front Face Material*
Level 1 X - Score (-1)	*Large, Walk-Up (Non-Portable)*	*4 Different Drinks*	*Touch Screen*	*Cannot See Drink Being Made*
Level 2 X - Score (1)	*Medium, Microwave-Sized (Portable)*	*8 Different Drinks*	*Buttons, Dials, Switch*	*Can See Drink Being Made*

When choosing which characteristics to include in the final design, the team decided to aim to create a product that is as simple and aesthetic as possible. By assigning weights or numeric, survey values to each response and tallying up the total number of responses, we calculated corresponding Y-Scores for each design to assess how they make our consumers feel. By comparing the respective X-Scores and Y-Scores, a total score with two data points can be plotted for each Level to determine which characteristics best suit the desired perception of our design. The characteristic values corresponding to each level are listed and graphed below.

Table 3A: Kansei Characteristic Table: Size/Drink Selection

X1	X2	Y1	Y2
1	1	0.62	0.70
-1	-1	-0.24	0.16
-1	1	0.32	-0.38
1	-1	0.43	-0.27

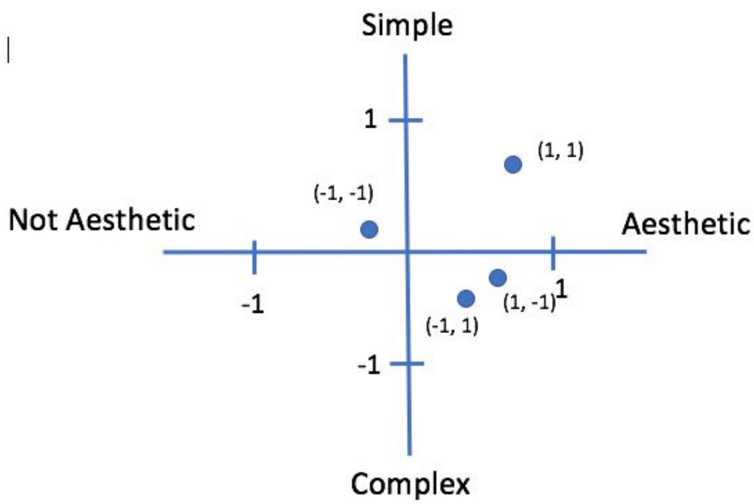


Figure 8A: Size/Drink Selection Kansai Analysis 1

Table 3B: Kansei Characteristic Table: Variety of Drinks/Front Face Material

X1	X2	Y1	Y2
1	1	0.53	0.68
-1	-1	-0.35	0.40
-1	1	0.26	-0.62
1	-1	0.55	-0.15

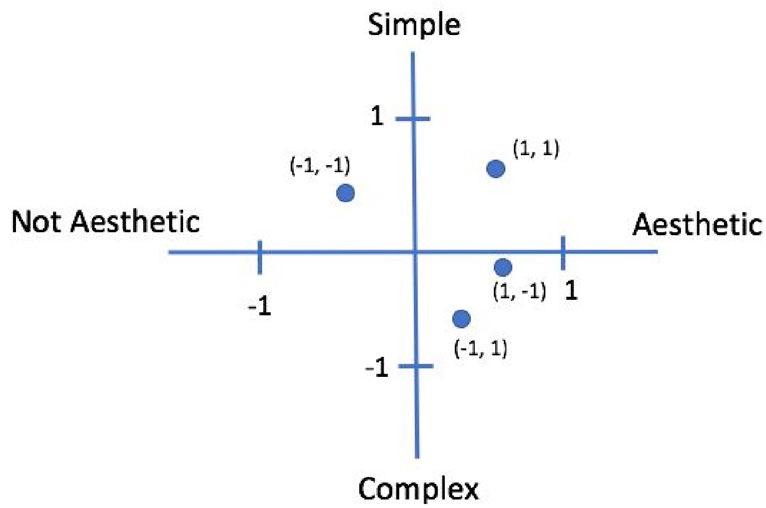


Figure 8B: Variety of Drinks/Front Face Material Kansai Analysis

From the graphs above, one can see that choosing a design with a medium-sized machine with up to eight different drink choices and a design with buttons that allows the user to see the drink being made lie in the upper right hand quadrant of the graph. This tells us that these are the levels of the characteristics that would most satisfy the desired perception of our design, therefore we will be sure to include them in our final design concept.

Product Differentiation

When customers see the Cocktail Cube, the intent is to differentiate it from a standard appliance and be identifiable for craftsmanship design. This was accomplished with a classic wood finish and furniture style embodiment and dimensions. It is intended to be a show piece rather than a piece of metal serving an arbitrary function. This will give the machine a more handmade look rather than an industrialized one.

An important aspect of the design of the cocktail cube is simplicity. Competitors seem to prefer a touchscreen and a massive feature list from which they can boast their product dominance, however, our exclusion of these features is intentional. The simplicity with which we designed our product interface is considered an advantage over other products. There are a series of turn knobs from which to indicate the ratio of fluid from each ingredient, an auto dispense button, and a manual dispense button. When auto dispense is activated, the sensors in the system are able to detect the size of the container and how much fluid is present. Once the ratios are set, the server needs only to place the glass under the dispenser and the cocktail cube will do the rest. If making several of the same drink, the server can use the hands-free design to quickly and accurately dispense the number of beverages required.

Ergonomic Analysis

To finish off our emotional analysis we looked at the ergonomics of our product to determine the final details of the product. We started by looking at how the buttons were placed on the machine. The average height was researched and determined to be 41-43’’, and the most comfortable position for using our user interface would be where there arms could easily reach the knobs. This way, they could see into the machine when they need to refill it. For this reason, we placed the buttons 12 inches from the base of the product, which would sit roughly 55’’ above the ground. Since the average height for men and women is roughly 5’6”, and the buttons are roughly 4’7” off the ground this is more or less an ideal height for comfortable functioning because it meets the user's chest.

We wanted to make the process of dispensing and cleaning as easy as possible, hence our button simply pushes to do so. One push dispenses, two pushes will stop dispensing, and finally, the cleaning of the device will be done automatically. This plays along with our button layout, where the knobs that control the ingredient concentration are laid out the same as how the ingredients are put in the machine, much like a grid. This way they knobs easily correspond to button layout, so users don't need to fumble with remembering what knob corresponds to what ingredient.

Microeconomic Analysis

Cost Structure

A simple cost analysis was conducted to determine the feasibility for a business model applying the requirements and a feature by feature analysis for profitability. The material cost for our Beta-Plus prototype was $210. While this may seem high, it is expected that many costs can be reduced both in bulk purchasing and minimizing components without reducing functionality. For example, while there are two arduinos, relay switches, and battery packs, cost can be reduced by contracting a company to build a single microcontroller which doesn’t possess the unnecessary functions and features of an arduino which can be purchased for far less.

Other observations concerned the physical embodiment of the artifact. Due to wood being somewhat expensive and heavy, future iterations may be considered to be housed in a plastic molding while still retaining the classic features of wood with a faux finish. This would save on material cost, distribution cost, and streamline the build process. A bill of materials is listed in Appendix K.

Demand Value

Our team generated a demand model based on our competitors product prices. Based on this graph, it was determined the optimal price for our product should be priced at $400.

Figure 9: Demand model displaying the trend in estimated competitors total product sales for first year

Profit Maximization Model

To better understand how our price would fit into our revenues we created a profit maximization model shown below.

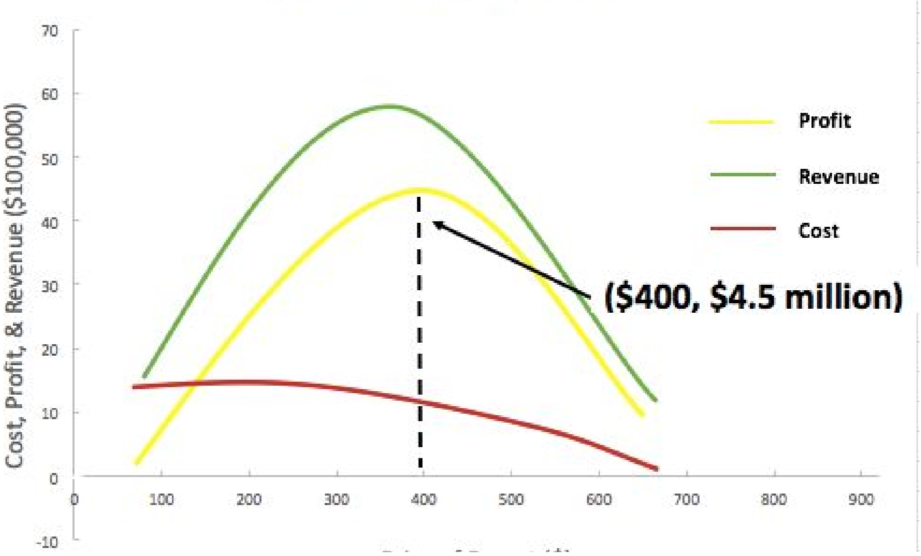


Figure 10: Profit Maximization Model Graph

Our model explains that $400 is the most profitable price to sell our product. Although we would attain more revenue at a slightly lower price, the cost would not justify the price. As the price for the product goes up, cost will go down, however the demand for the product will also drop according to our kansei surveys shown in Appendix A.

Investment Analysis

After performing a pro forma analysis, the break even point for our product would be in 2021 based on an initial $1M investment initially at a 6% interest rate. While the business would begin making profit in its first year, it would be spent on principal of the initial investment loan.

Table 4: Our overall investment analysis from 2018-2022

Pro Forma Income Statement		2018	2019	2020	2021	2022
Units Sold		3,000	3750	4688	5860	7325
Net sales	$	1,200,000	1,500,000	1,875,200	2,344,000	2,930,000
Cost of goods sold		-420,000	-525,000	-656,320	-820,400	-1,025,500
Gross profit		780,000	975,000	1,218,880	1,523,600	1,904,500
Distribution expense		-300,000	-375,000	-468,800	-586,000	-732,500
Selling, general and administrative expense		-120,000	-150,000	-187,520	-234,400	-293,000
Other operating income		0	0	0	0	15,002
Operating income		360,000	450,000	562,560	703,200	894,002
Interest expense		-60,000	-48,300	-44,334	0	0
Income from continuing operations before taxes		300,000	401,700	518,226	703,200	894,002
Tax expense from continuing operations		-105,000	-140,595	-181,379	-246,120	-312,901
Net income from continuing operations	$	195,000	261,105	336,847	457,080	581,101
Investment Expense		-195,000	-261,105	-336,847	-207,048	0
Net Income After Investment Expense		0	0	0	250,032	581,101

To complete our financial calculations, we made several assumptions:

- 25% annual growth rate in sales
- SG&A is 10% of revenue
- Retail markup of 25%
- Corporate tax rate of 35%
- Straight line depreciation of assets
- Surveyed data is representative of target market

Marketing Analysis

Target Market

The market size for the Cocktail Cube is comprised of businesses who serve mixed drinks. There are approximately 750,000 of these business in the US made up of bars, restaurants, and catering companies. Out of the 750,000 potential customers, our target market are high volume businesses who may have a need for a device to improve the efficiency of servers and bartenders when patronage is at its highest.

Requirements Gathering

The marketing study consisted of interviews with bartenders to determine what the most time consuming or difficult problems encountered during the process of crafting a cocktail. It was discovered that the most significant problem was finding and mixing ingredients so this was one of the primary focal points of determining attributes and objectives for the product.

In the conjoint analysis, questions were related to number of ingredients desired, a determination on a satisfactory dispensing time, and price. Although this information was received and considered, it was disregarded largely due to the fact that the survey recipients were not our direct customers, therefore, their consideration of importance and reflection on our product wasn't weighted very heavily when making design decisions. Instead, design decisions were based ultimately on the emotional and aesthetic analysis and also the microeconomic analysis rather than survey input.

Sustainability Analysis

When designing our product, we had to consider the environmental impacts associated with its production, distribution, and recyclability. We analyzed various stages in our product's development process, which included the raw materials used, technology used in manufacturing our product, the impact during use, and it's end of life. At each stage, we primarily analyzed the overall energy consumption, since higher energy consumption rates mean higher carbon dioxide emission rates [1].

Raw Materials

Our final product consists of predominantly plastic and metallic materials. Based on our customer interviews and our kansei analysis, it was determined that most customers preferred the wooden aesthetic appearance. To retain the same appearance, but for our product to have a more environmentally positive impact, we used recyclable wood-plastic composite boards for constructing the products main frame [2]. Other plastic materials include the ingredient containers and the tubing used in dispensing ingredients, which are also recyclable. The metallic materials include the electrical components of the user interface and any screws within the frame. The wires connecting the pumps to the user interface, the knobs and buttons of the product, and the screws could be recycled for scrap metal.

Technology used

Our final product is manufactured primarily using table-saws and cordless hand held drills, which consume a considerable amount of energy. However, we assumed the overall energy consumption from these tools would be low because of the simplistic procedure in manufacturing each component of the products frame. We first measure the dimensions of each board for the frame using basic measuring tools, then quickly cut to size using the table saw. Second, we make accurate measurements to where screws would be located, then quickly drill in screws to fasten the boards and other product components together. By simplifying the manufacturing procedure, the time required and energy consumption from the usage of each tool is minimized.

Impact from Use

During use, our final product's main energy consumption comes from the pumps and the LED system. Each pump requires 12V of power per use with a maximum of 8 pumps within the product. However, since the dispensing time from each container is quite fast, we assumed the overall energy consumption from each use would be low. We also assumed our lighting system would consist of low power consuming LED's, thus further reducing overall power consumption and carbon emissions.

End of Life Analysis

After the product's lifespan of 5 years is over, most of the components can be recycled. To reiterate, the plastic components from the frame can be recycled or reused for other projects, and the electrical components can be recycled for scrap metal.

Our Product vs. Competitors

In comparison to competitors, our product uses more recyclable plastic materials and less metals and electronics than other similar products. The user interface used in competitor products is more complex and requires more power, some using a touch screen and RFID technology. Some competitors products also have more functions, hold more ingredients, and use a larger number of LED's, which also require more power. To summarize, our product is almost entirely recyclable and uses less power, corresponding to less carbon dioxide emissions.

Product Development Process

In this section we will present our team's design structure matrix and design process model, which details the step by step process of our products development and production. Our team's design process was structured towards mass concept generation and then mass prototyping of a singular concept.

We first focused on defining our design problem, then began defining the customers that would most benefit from our solution. Once we selected our targeted customer audience, we began surveying and interviewing to better understand their product preferences. Once we acquired data from these surveys and interviews, we were able to shorten our attributes to a select few and focus on those for prototyping while researching other products for comparison. We then finalized our products functional requirements, which reflected our customers needs/wants and technology found in similar products. We then generated many design concepts and eventually selected one to develop into the Alpha and Beta prototypes. After conducting conjoint and kansei survey analysis, we minimized our attributes and concentrated on those that were most important for the final product. Additionally, we made the corresponding CAD design changes to our product as we began making the necessary functionality improvements.

At the beginning of the semester, we all aspired to design our product using a more linear procedure as detailed in the APD design process model. However, as the term progressed, we experienced numerous changes in customer needs and preferences. As a result, we learned our product attributes and characteristics had to be constantly changed to account for those needs, and weren't necessarily finalized until near the development of the final product. Our design process model and a respective design structure matrix can be seen below on page 34-35.

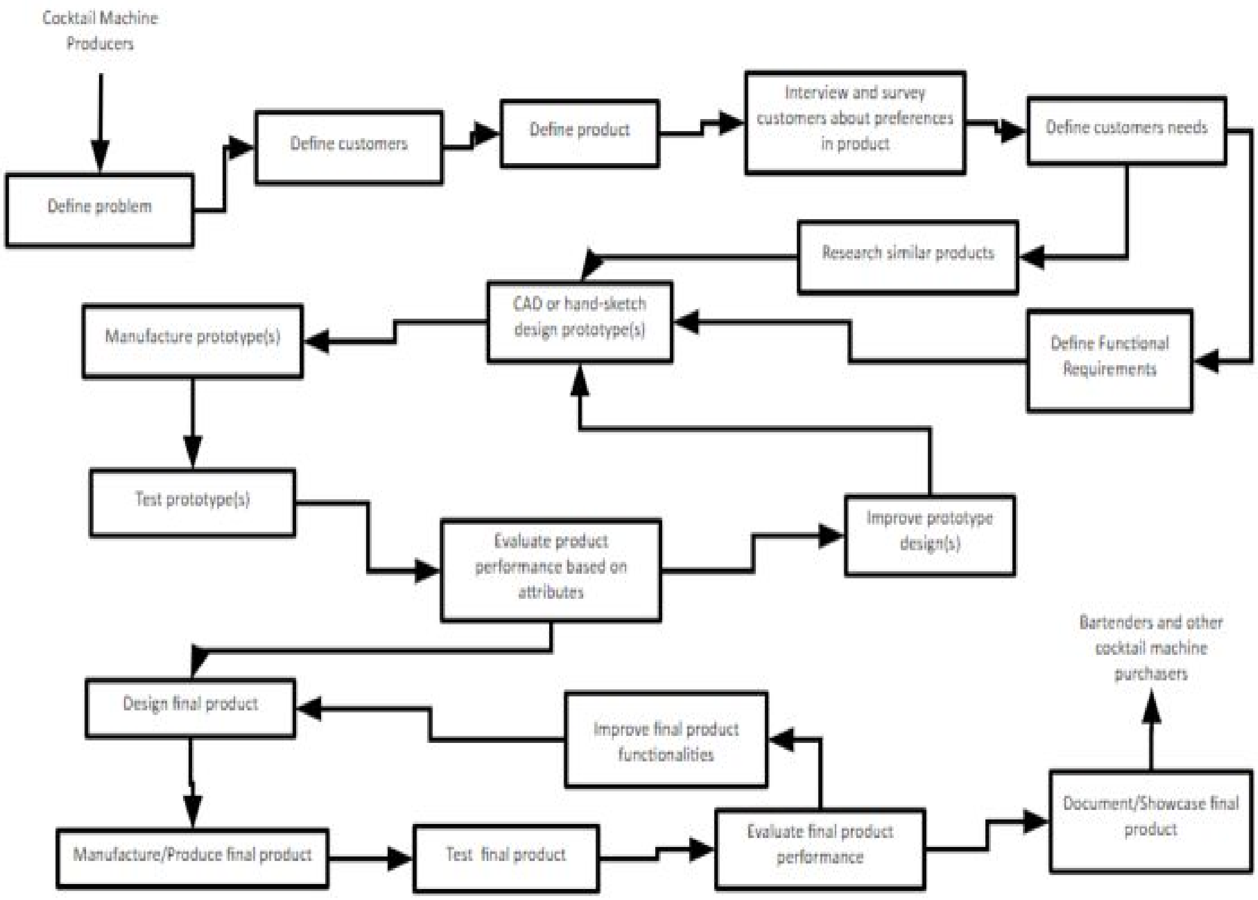


Figure 11: Design Process Model

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Define Problem	1																	
Define Customers	2	x																
Define Product	3		x															
Interview/Survey customers about product preferences	4			x														
Define customer needs	5				x													
Research similar products	6					x												
Define functional requirements	7					x												
Design Prototype(s)	8						x	x					x					
Manufacture Prototype(s)	9								x									
Test Prototype(s)	10									x								
Evaluate prototype(s) performance	11										x							
Improve prototype design(s)	12											x						
Design final product	13											x						x
Manufacture final product	14													x				
Test Final product	15														x			
Evaluate final product performance/results	16															x		
Improve Final Product functionalities	17																x	
Documentation of final product and showcase	18																	x

Figure 12: Design Structure Matrix

Product Broader Impact

Being a team consisting of all young adults approaching graduation at the University of Michigan in Ann Arbor, we've spent plenty of time going out with friends to get drinks at the local, popular bars and have experienced the negative effects of these bars at its busiest hours. When you're living on a college campus, there's only a limited number of bars that people go to, and for that reason, the few most popular bars get very crowded, very fast. As you finally approach the front of the enormous line of these bars and make your way inside, you find another line at the bar. You wait and wait while wasting time at the bar instead of dancing and talking with your friends.

As weekly goers to these bars, spending 2-3 times a week going out with friends to catch up and have drinks, we came together as a group and decided we wanted to fix this problem and design the autonomous cocktail machine. As engineers, designers, and also customers who would potentially see a product like this in action, we have great insight on the problem at hand and actually care about solving this quite annoying problem in people's everyday lives.

To sum things up, as a group, each of us has always admired and desired to create design that will make people's lives easier and as a result, more effective. When we came together, we wanted to choose a project that would accomplish this. We believe our Cocktail Cube will, in fact, do just that and for multiple parties as well. Living in a society that is becoming more and more automated each year, we saw an opportunity to incorporate this into the bar scene. Looking at past products, no one has addressed the commercial side of autonomous drink making this created our niche. There is a reason we are moving towards this technological advance, and it brings us back to our original goal: to make people's lives easier and as a result, more effective. This was our main objective as a team, and guided us through our decision making to produce our product.

Conclusion

On a busy night, popular bars and clubs often have long waits to get a drink, and when customers are final able to buy their favorite cocktail they are consistently made. The cocktail cube is the perfect solution of commercial cocktail production. When trying to come up with a solution to this problem, we analyzed data collected from marketing, conjoint, and kansei surveys to determine the best features for such a product. We started by creating a CAD model and performed analysis on components to make sure our product fit the needs of our consumer. Once the designated features of the product were identified we moved to producing two prototypes to embody a final product.

From the prototypes we learned about user interface systems, proper electronics use around liquids, and determine the best finish on the exterior to fit our consumer needs. The final product will be manufactured to allow for simultaneous dispensing of ingredients and quick signal processing. As of now our machine can dispense a drink in 13 seconds, and we are aiming for a final product to dispense a drink in under 10 seconds. We hope to continue making improvements on our device and eventually have it sold to bars nationwide.

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4. “Barbotics Cocktail Machine and Robotic Bartender”, *Barbotics Cocktail Machine and Robotic Bartender.* [Online]. Available: https://www.barbotics.com/studios. [Accessed: 24-Sep-2017].
5. “Products & Prices,” THE QUBE. [Online]. Available: http://theqube.de/en/products.htm. [Accessed: 24-Sep-2017].
6. “The Inebriator”, *The Inebriator*. [Online]. Available: https://www.theinebriator.com/. [Accessed: 24-Sep-2017].
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8. J. Turi, “Monsieur robotic bartender pours libations at home for $1,499 (hands-on),” *Engadget*, 14-Jul-2016. [Online]. Available: https://www.engadget.com/2013/10/01/monsieur-robotic-bartender/. [Accessed: 24-Sep-2017].

Appendices

Appendix A: Survey Results

Conjoint Survey Analysis: First one

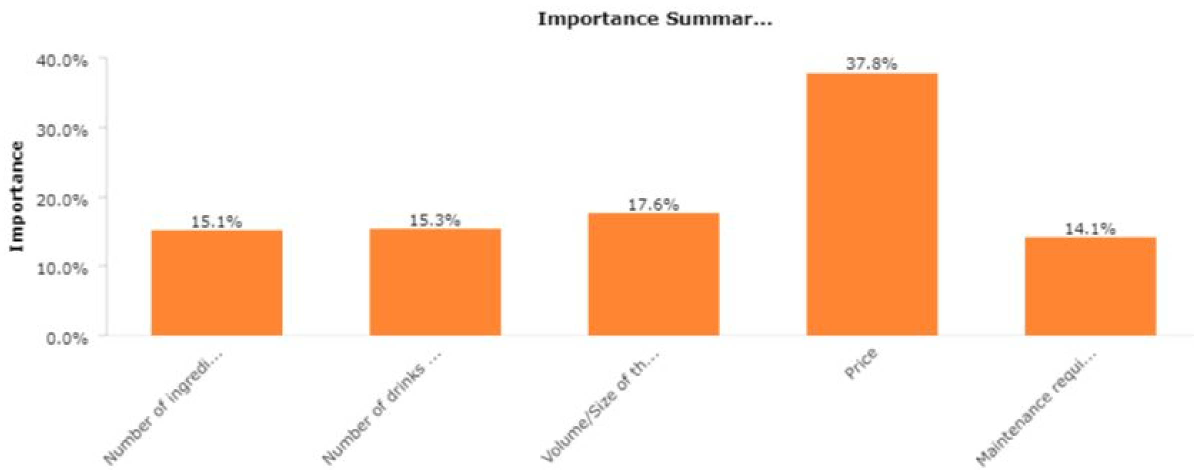


Figure A1: Graph showing that customers chose price as the most important attribute when choosing a product

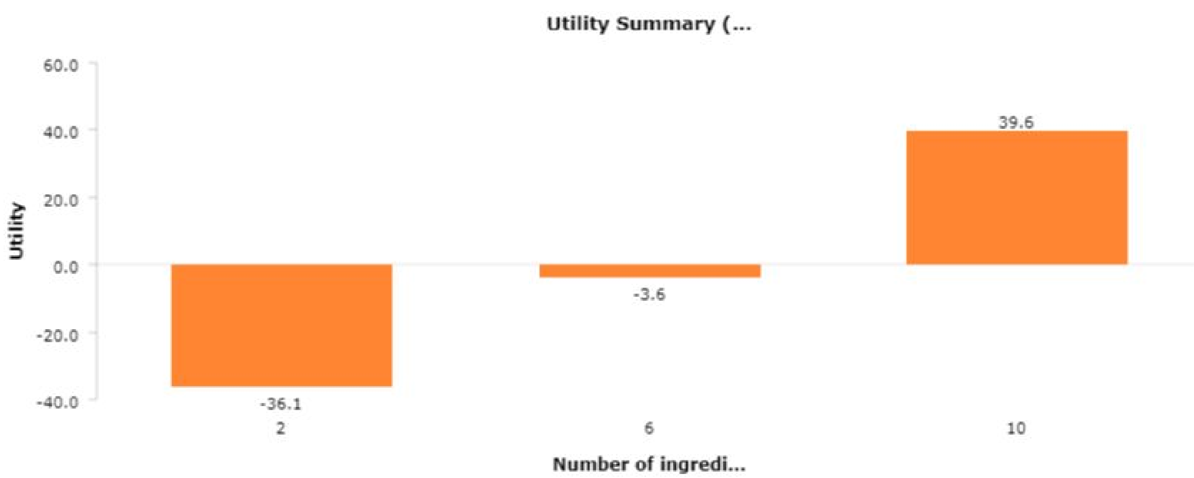


Figure A2: Graph showing that customers preferred a larger number of ingredients in our product

Conjoint Survey: Marketing Analysis

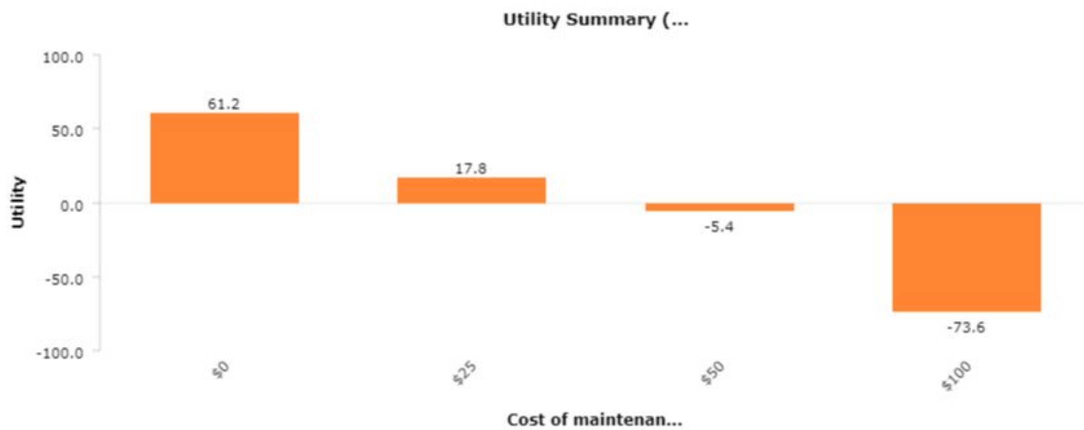


Figure A3: Graph showing that as the cost of maintenance of our product increased, customer preference for that product decreased

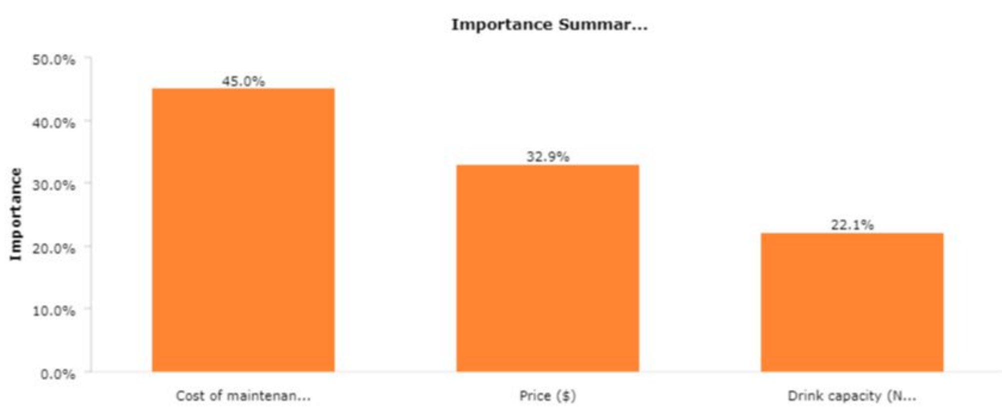


Figure A4: Graph from conjoint survey analysis in marketing, showing cost of maintenance was the most important characteristic to customers for purchasing our product

Appendix B: Marketing Analysis

Figure B1: Demand model displaying the trend in estimated competitors total product sales for first year

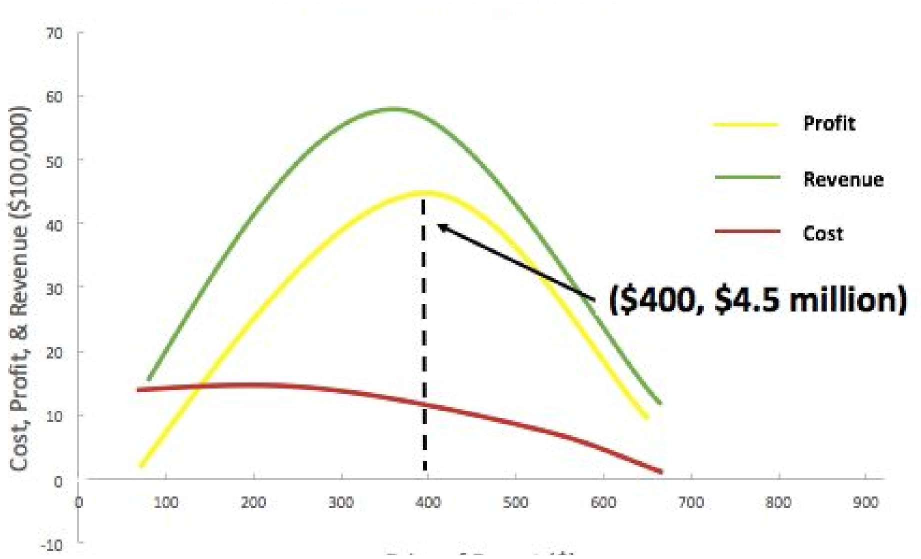


Figure B2: Profit Maximization Model Graph

Appendix C: CAD Images

Figure C1: Final product CAD design

Figure C2: Current product CAD design

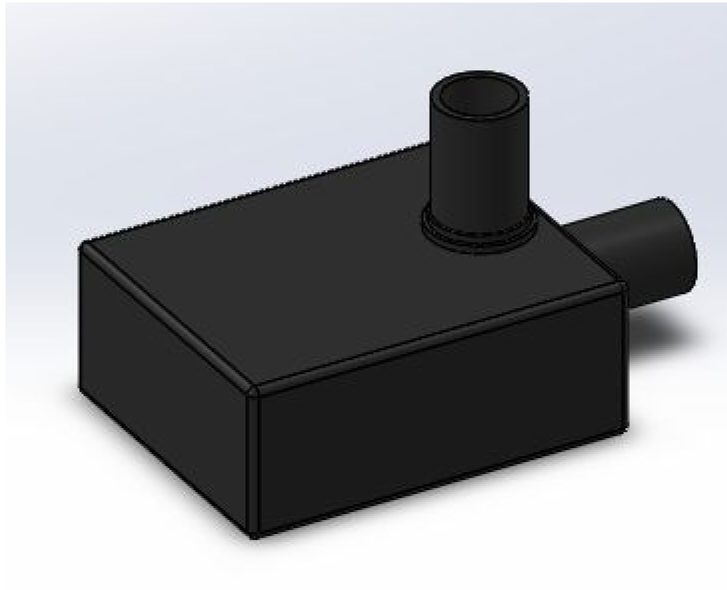


Figure C3: Pump used for each ingredient container

Figure C4: Ingredient container and pump system

Appendix D: Attributes and Characteristics

Attribute	Importance			Characteristics				
		Steps to Use	Size	Weight	Strength	Cost	Number of Parts	Dispensing Time
Ease of Use	5	5					4	3
Speed	4	4					4	4
Maintenance	4	4	4				3	
Versatility	4	4			2		2	
Security	3							
Portability	2		2	2			3	
Affordability	2					2	2	
Ease of Installation	2		2	2				
Aesthetics	2		2	2				
Durability	2		2	2	2		2	

Figure D1: A design mapping matrix that translates our design attributes to measurable characteristics. It's important for our product to take into consideration steps to use, size, weight, number of parts, cost, and dispensing time.

Table D1: A chart categorizing the design characteristics into objectives or requirements and showing the target or minimum/maximum value determined for each characteristic

Design Characteristic	**Objective or Requirement**	**Min/Max or Target Value**	**Measuring Method**
Steps to Use	Objective	Min	Physical Actions
Size	Objective	Min	Inches
Weight	Objective	Min	Pounds
Strength	Objective	Max	Stress/Strain
Cost	Requirement	Min	Monetary
Number of Parts	Objective	Min	Count
Dispensing Time	Requirement	Target	Minutes

Appendix E: Previous Design Concepts

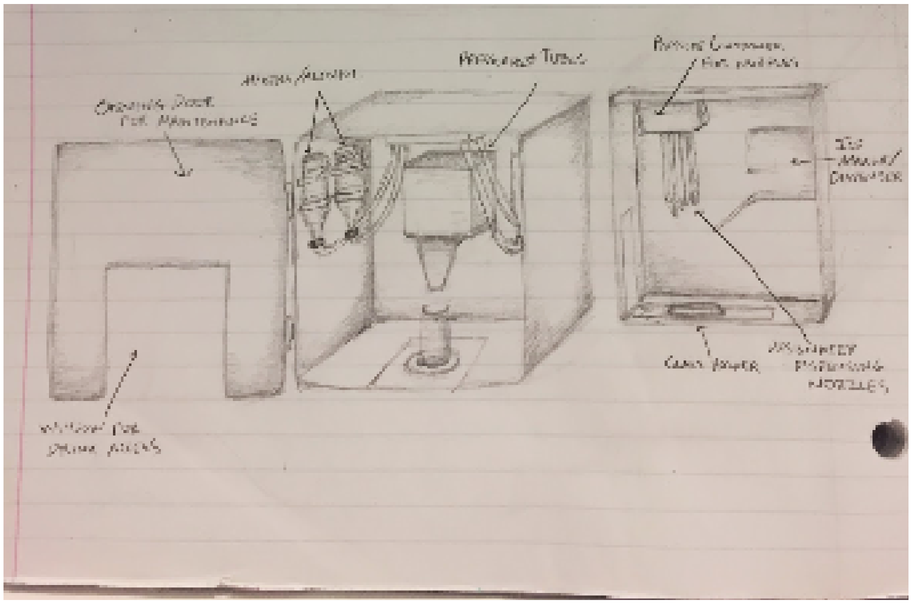


Figure E1: A diagram of concept 1 and its ability to make drinks, the size would be that close to a microwave

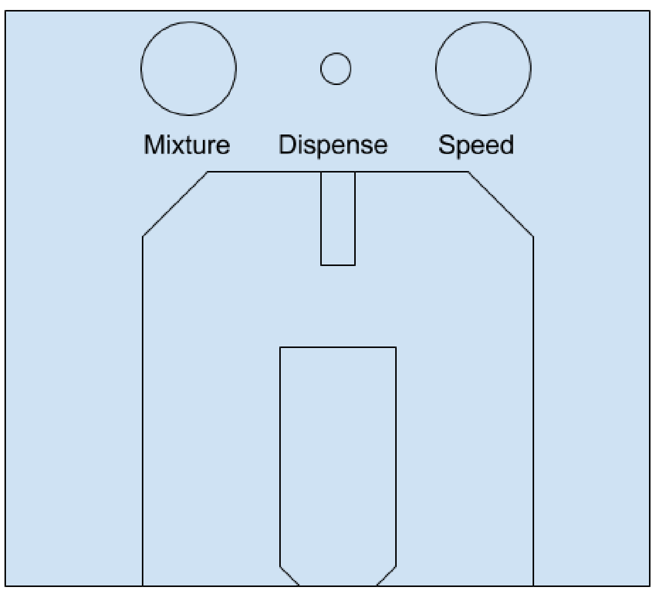


Figure E2: A diagram of concept 2, with dials that represent the concentration of the two ingredients and the speed needing to be dispensed at. There is a button for dispensing once the inputs have been set.

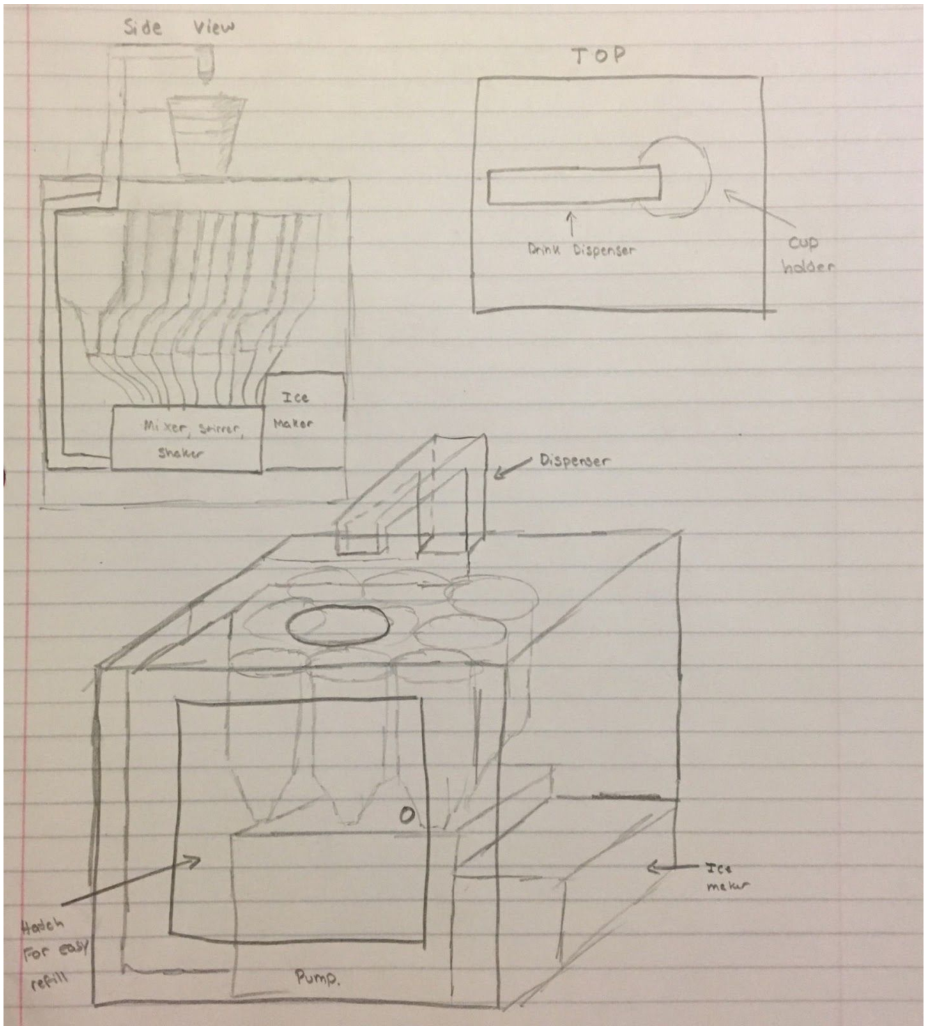


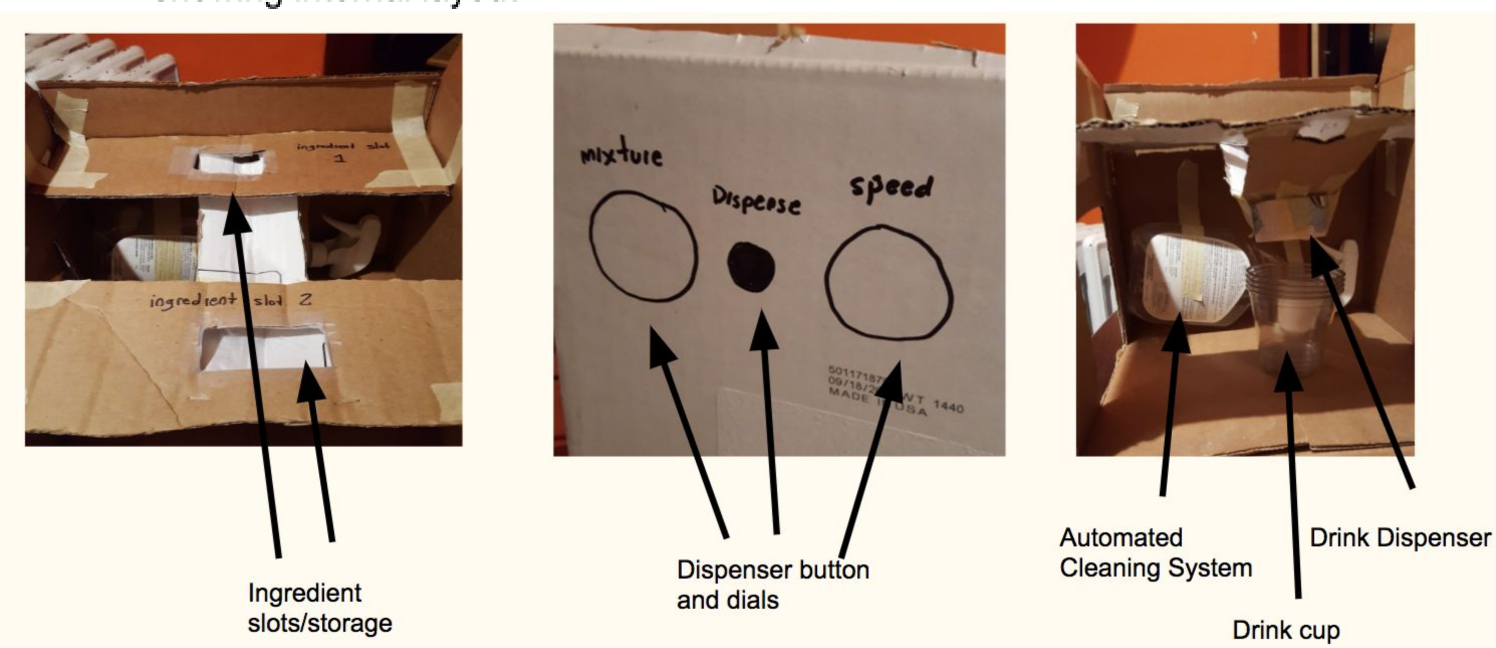
Figure EC: A diagram of Concept 3: Having a larger design, dispensing spout, and a more complex user interface.

Appendix F: Prototype Images

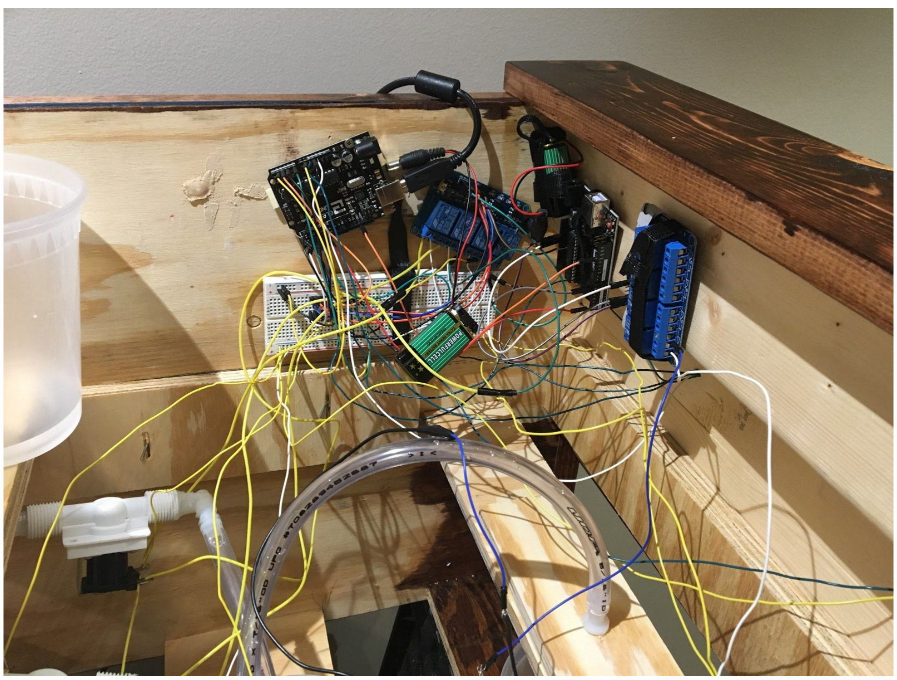
Alpha Prototype:

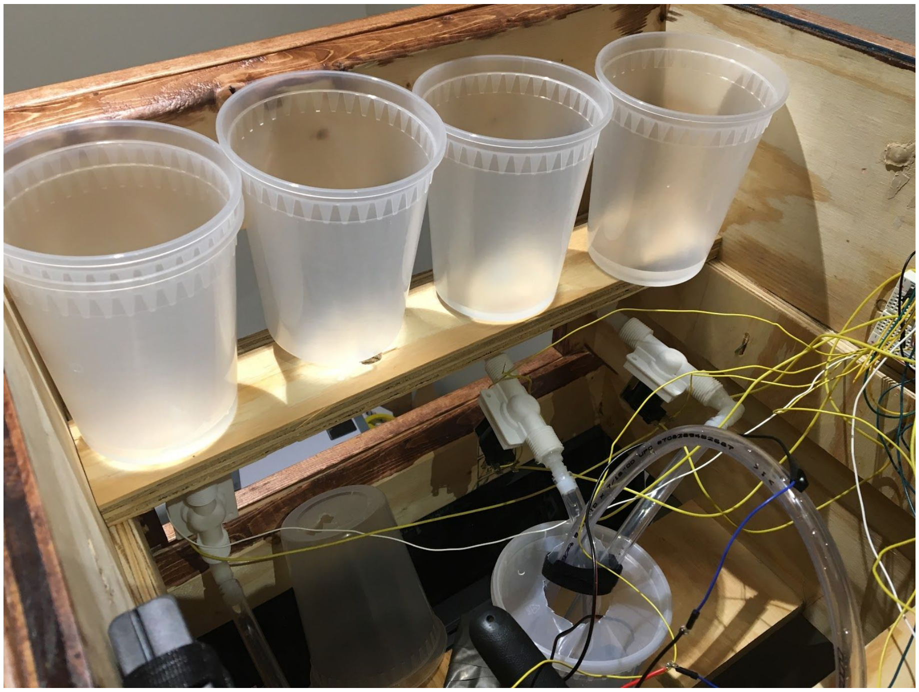
External view of alpha prototype showing internal layout

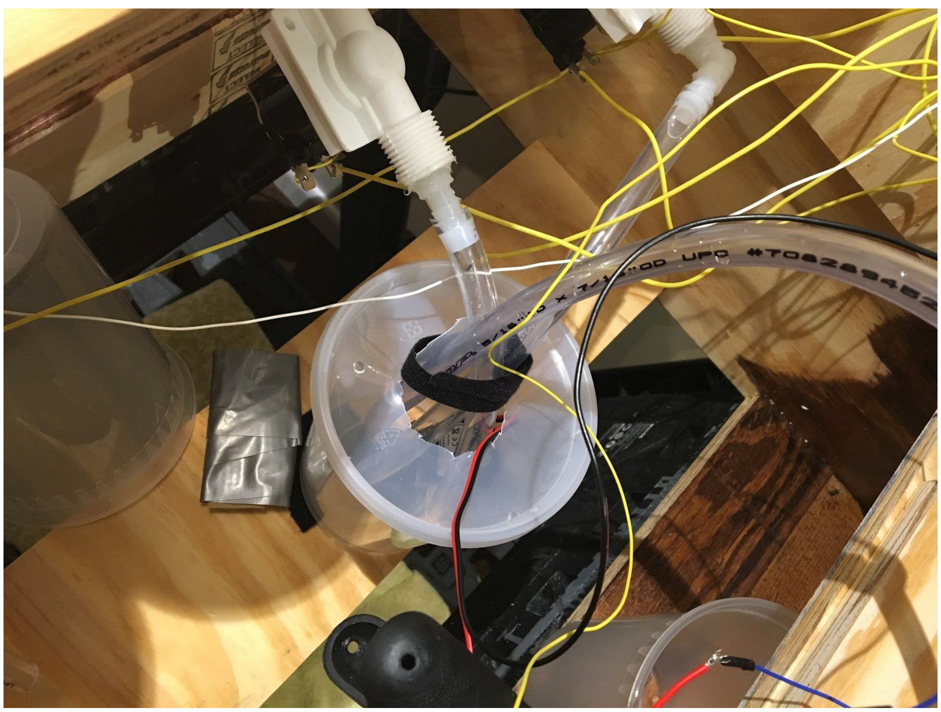
Front view of alpha prototype



Beta Prototype:







Appendix G: Product Positioning Chart

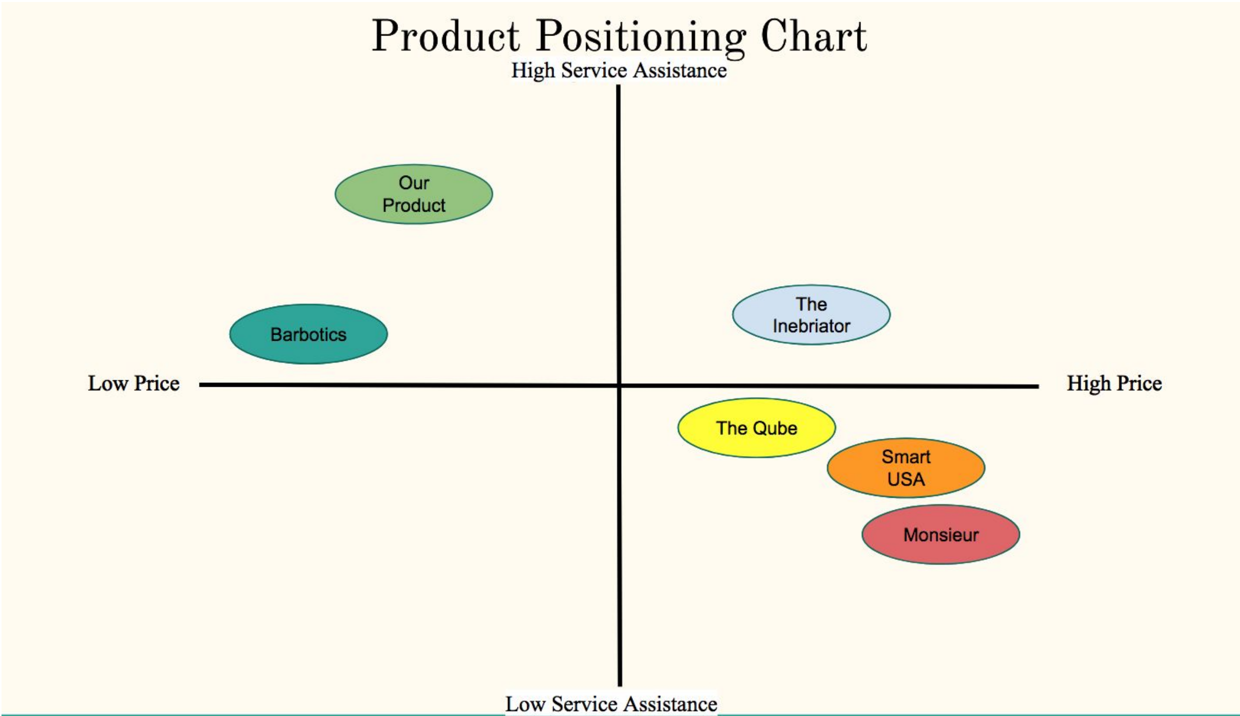


FIgure G1: Product Positioning chart comparing our product to the leading competitors.

Appendix H: Previous Designs

Figure H1: Shows the barbotics cocktail machine

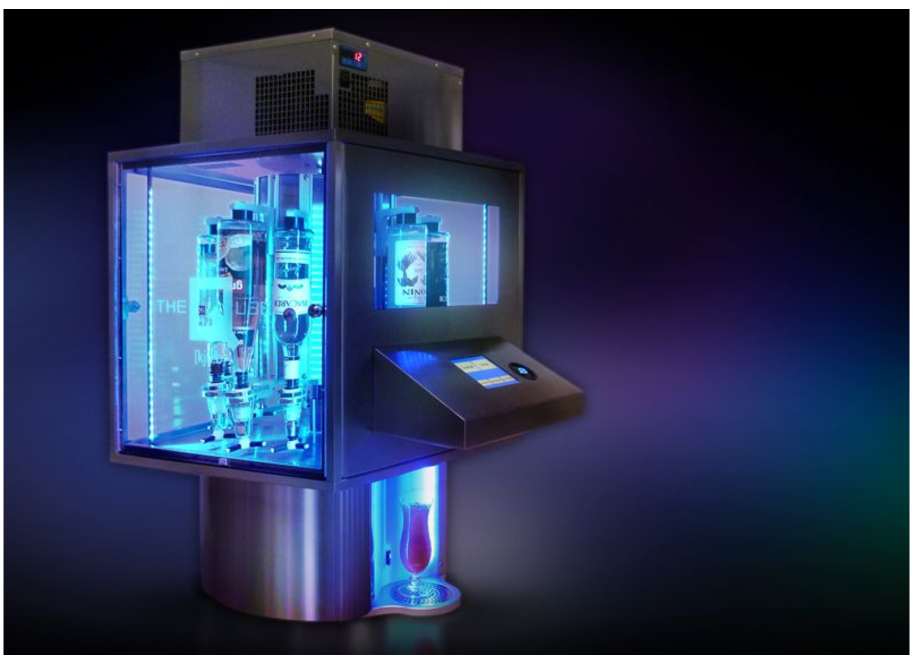


Figure H2: Shows the Qube cocktail machine

Figure H3: The Inebriator

Figure H4: Shows the Monsieur Robotic Bartender machine

Figure H5: Shows the Smart Bar USA Bartender machine

Appendix I: Engineering Analysis

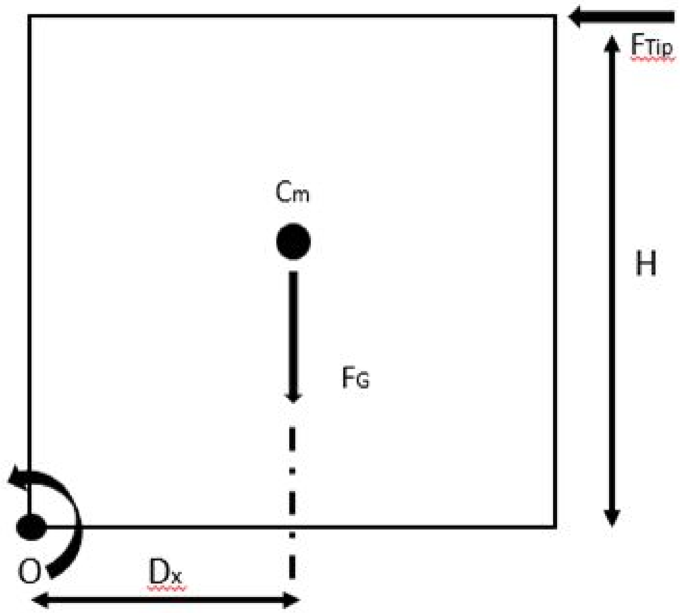


Figure IA: Free body diagram of the X-Y plane view of final product for tipping force analysis

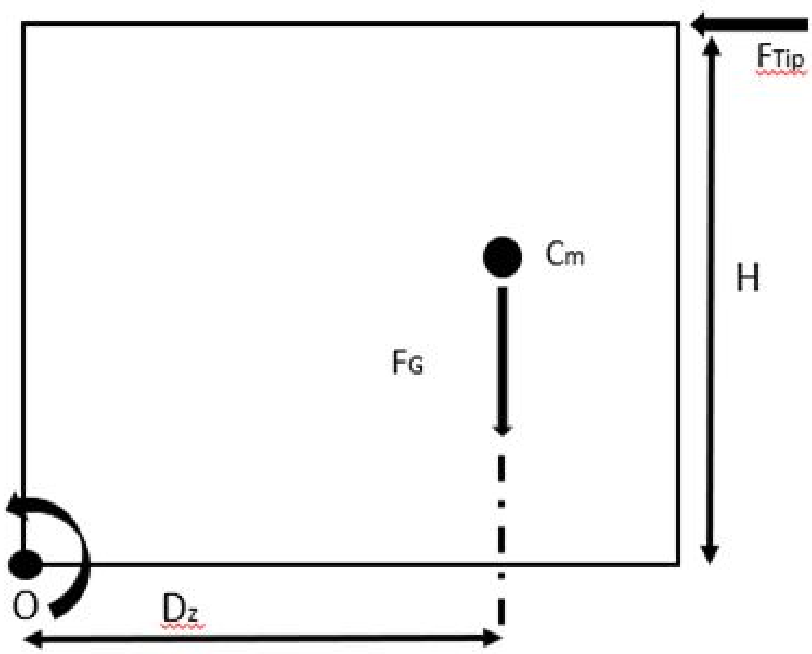


Figure IB: Free body diagram of the Y-Z plane view of final product for tipping force analysis

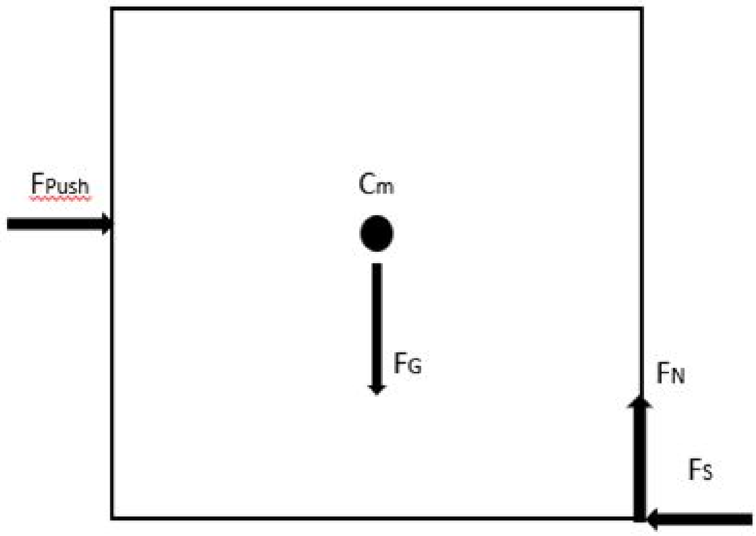


Figure IC: Free body diagram of the X-Y plane view of final product for pushing force analysis

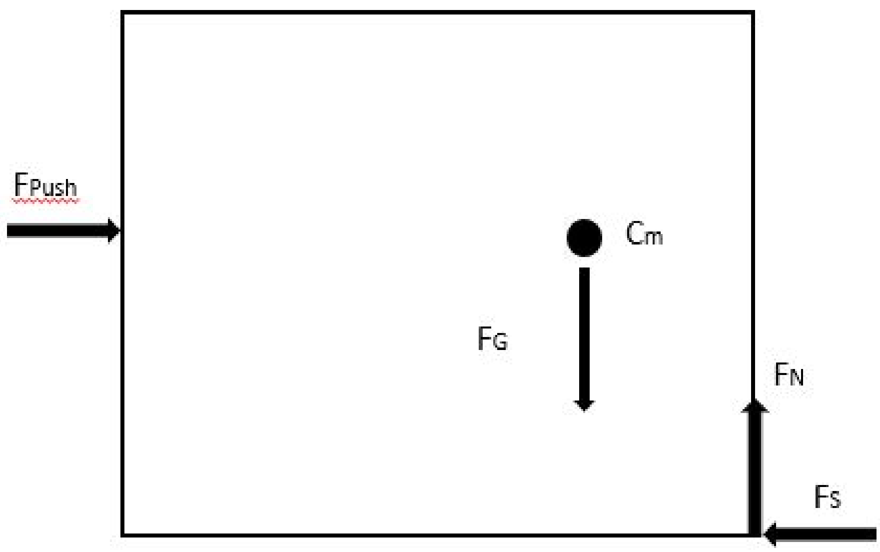


Figure ID: Free body diagram of the Y-Z plane view of final product for pushing force analysis

Appendix J: Microcontroller Code

```
//Global Varialbes for dispensing
int button = 1; //button for dispensing drink
int buttonpin = 5;
// Values for the pump
int pump;
int pumpPin = 6;
//Values that come in from the potentiometer
int ingr1 = A0;
int ingr2 = A4;
int ingr3 = A2;
int ingr4 = A3;
//Values for the timer function for concentration
int ingr1_con;
int ingr2_con;
int ingr3_con;
int ingr4_con;
//Create values for the relays to turn the valves
int relay1 = 1;
int relay2 = 2;
int relay3 = 3;
int relay4 = 4;

void setup() {
  // put your setup code here, to run once:

Serial.begin(9600);
  pinMode(relay1, OUTPUT);
  pinMode(relay2, OUTPUT);
  pinMode(relay3, OUTPUT);
  pinMode(relay4, OUTPUT);
  pinMode(pumpPin, OUTPUT);

  pinMode(buttonpin, INPUT);
  pinMode(ingr1, INPUT);
  pinMode(ingr2, INPUT);
  pinMode(ingr3, INPUT);
  pinMode(ingr4, INPUT);

  digitalWrite(relay1, HIGH);
  digitalWrite(relay2, HIGH);
```

```
  digitalWrite(relay3, HIGH);
  digitalWrite(relay4, HIGH);
  digitalWrite(pumpPin, HIGH);
  Serial.println("App initialized");
}
void loop() {
  // put your main code here, to run repeatedly:
      //Serial.println(button);
//Serial.println(pumpPin);
  button = digitalRead(buttonpin);
  //Serial.println(button);
  delay(100);
  //button = 0;
  if(button == 0)
  {
    Serial.println("button pressed");
    digitalWrite(buttonpin,HIGH); // reset button state
    Serial.println("collecting ingredients");
    ingr1_con = analogRead(ingr1);
    ingr2_con = analogRead(ingr2);
    ingr3_con = analogRead(ingr3);
    ingr4_con = analogRead(ingr4);
    Serial.println(ingr1_con);
    Serial.println(ingr2_con);
    Serial.println(ingr3_con);
    Serial.println(ingr4_con);

    ingr1_con = map(ingr1_con, 0, 650, 0, 10);
    ingr1_con = constrain(ingr1_con, 0, 10);
    ingr2_con = map(ingr2_con, 0, 650, 0, 10);
    ingr2_con = constrain(ingr2_con, 0, 10);
    ingr3_con = map(ingr3_con, 0, 650, 0, 10);
    ingr3_con = constrain(ingr3_con, 0, 10);
    ingr4_con = map(ingr4_con, 0, 650, 0, 10);
    ingr4_con = constrain(ingr4_con, 0, 10);
    dispense1();
  }
}
void dispense1()
{
   Serial.println("initiating relays");
   digitalWrite(relay1, LOW);
   delay (ingr1_con * 1000);
```

```
  Serial.print("ingr1_con = ");
  Serial.println(ingr1_con);
  digitalWrite(relay1, HIGH);
 delay(100);
  digitalWrite(relay2, LOW);
  delay(ingr2_con * 1000);
  Serial.print("ingr2_con = ");
  Serial.println(ingr2_con);
  digitalWrite(relay2, HIGH);
  delay(100);
  digitalWrite(relay3, LOW);
  delay(ingr3_con * 1000);
  Serial.print("ingr3_con = ");
  Serial.println(ingr3_con);
  digitalWrite(relay3, HIGH);
  delay(100);
  digitalWrite(relay4, LOW);
  delay(ingr4_con * 1000);
  Serial.print("ingr4_con = ");
  Serial.println(ingr4_con);
  digitalWrite(relay4, HIGH);
 Serial.println("Relays initiated.");
  dispense2();
}
void dispense2() //Dispense funtion for the pump
{
 delay(100);
 Serial.println("Initiating Pump");
 digitalWrite(pumpPin, LOW);
 delay(5000);
 digitalWrite(pumpPin, HIGH);

 }
```

Appendix K: Bill of Materials

Descr	Qty	Price	Total - 1 Unit	Bulk Purchasing
Potentiometer	8	$1.00	$8.00	$4.00
Microcontroller	1	$25.00	$10.00	$5.00
Velcro	1	$5.00	$5.00	$2.50
Tubing	6	$0.45	$2.70	$1.35
Plastic Molding	1	$35.00	$35.00	$17.50
Battery Pack	1	$4.00	$4.00	$2.00
Batteries	8	$1.00	$8.00	$4.00
Feet	4	$1.00	$4.00	$2.00
Containers	8	$1.00	$8.00	$4.00
Fluid Pump	8	$10.00	$80.00	$40.00
Relay Module	2	$7.00	$14.00	$7.00
Total Cost			$178.70	$89.35