Fall 12-10-2017

Group G: Drink Mixer II

Yvette Anguiano  
Washington University in St. Louis

Tristram Wilson  
Washington University in St. Louis

Jacob Rother  
Washington University in St. Louis

Follow this and additional works at: https://openscholarship.wustl.edu/mems411

Part of the Mechanical Engineering Commons

Recommended Citation
Anguiano, Yvette; Wilson, Tristram; and Rother, Jacob, "Group G: Drink Mixer II" (2017). Mechanical Engineering Design Project Class. 73.  
https://openscholarship.wustl.edu/mems411/73

This Final Report is brought to you for free and open access by the Mechanical Engineering & Materials Science at Washington University Open Scholarship. It has been accepted for inclusion in Mechanical Engineering Design Project Class by an authorized administrator of Washington University Open Scholarship. For more information, please contact digital@wumail.wustl.edu.
Executive Summary

We, group G, want to address the needs of the restaurant industry by facilitating it with the products, alcoholic beverages, that often brings in the most income in a night for the business and for its bartenders. Mixing drinks takes specialized attention, energy, and time and can be a stressful task for bartenders to perform when a restaurant is packed with customers. Waits become longer and drink orders back up until the restaurant empties again. Our group strives to create a product that will ensure each customer is served with fast and efficient service, while still providing the special attention to a specific order. Our concept, a drink mixer, will deliver drinks in a timely and correct manner to help bartenders make more drinks at a time and address customers during high traffic times.

Our group created a project to develop this drink mixer. We interviewed bartenders and other consumers to get their thoughts and suggestions on an ideal product for their bar. Using these ideas as inspirations, we developed various concepts that could achieve these needs. We rated our designs based on their manufacturability, cost, components, reliability, and more characteristics to ensure our chosen design could be completed in the time and budget constraints we had. Our chosen concept achieved most of our design conditions and we set quantitative performance goals to evaluate our product. The drink mixer would carry various ingredients, shake or stir our beverage, make different drink recipes, and be controlled by pre-set buttons. We performed various design analysis to help create each component in the system. Once we began buying and assembling materials, the product we envisioned proved to be more difficult to make as we progressed over the semester.

The process revealed various faults in our design and building process. Overall, we learned as a group about the design process, budgeting, using Arduino and other electrical components, and the build and testing process. This report offers details our project from start to finish of envisioning, designing, and building our drink mixer, while also showing our insight and reflection on the entire process.

MEMS 411: Senior Design Project

Group G: Drink Mixer

Yvette Anguiano
Tristram Wilson
Jacob Rother
TABLE OF CONTENTS
List of Figures .............................................................................................................................. 5
List of Tables ............................................................................................................................... 7
1 Introduction and Background Information ............................................................................... 8
  1.1 Initial Project Description ........................................................................................................ 8
  1.2 Existing Products ..................................................................................................................... 8
  1.3 Relevant Patents ..................................................................................................................... 10
  1.4 Codes & Standards ................................................................................................................ 11
  1.5 Project Scope ....................................................................................................................... 11
  Error! Bookmark not defined.
  1.6 Project Planning .................................................................................................................... 14
  1.7 Realistic Constraints ............................................................................................................ 15
    1.7.1 Functional ....................................................................................................................... 15
    1.7.2 Safety ............................................................................................................................ 15
    1.7.3 Quality .......................................................................................................................... 15
    1.7.4 Manufacturing ................................................................................................................ 15
    1.7.5 Timing ............................................................................................................................ 15
    1.7.6 Economic ....................................................................................................................... 15
    1.7.7 Ergonomic ..................................................................................................................... 15
    1.7.8 Ecological ..................................................................................................................... 16
    1.7.9 Aesthetic ...................................................................................................................... 16
    1.7.10 Life Cycle .................................................................................................................... 16
    1.7.11 Legal ............................................................................................................................ 16
  1.8 Revised Project Description ................................................................................................... 16
2 Customer Needs & Product Specifications .............................................................................. 17
  2.1 Customer Interviews ............................................................................................................ 17
  2.2 Interpreted Customer Needs .................................................................................................. 20
  2.3 Target Specifications ............................................................................................................. 21
3 Concept Generation ................................................................................................................ 23
  3.1 Functional Decomposition ...................................................................................................... 23
  3.2 Morphological Chart ............................................................................................................ 24
  3.3 Concept #1 – “No shaking, simple delivery and making” ..................................................... 25
  3.4 Concept #2 – “Shaking and Stirring Machine” ...................................................................... 26
  3.5 Concept #3 – “Linear Arm Movement” ................................................................................ 27
3.6 Concept #4 – “No Shaker, Rotating Plate” ................................................................. 28
3.7 Concept #5 – Complex stirring and shaking ............................................................... 29
3.8 Concept #6 – Shaking rotating plate ........................................................................... 30
4 Concept Selection .......................................................................................................... 31
4.1 Explanation of Winning Concept Scores .................................................................. 31
4.2 Explanation of Second-Place Concept Scores ......................................................... 31
4.3 Explanation of Third-Place Concept Scores .............................................................. 31
4.4 Summary of Evaluation Results ................................................................................ 32
5 Embodiment & Fabrication plan .................................................................................. 33
5.1 Isometric Drawing with Bill of Materials ................................................................. 33
5.2 Exploded View ............................................................................................................ 36
6 Engineering Analysis ..................................................................................................... 36
6.1 Engineering Analysis Results .................................................................................... 36
  6.1.1 Motivation .................................................................................................................. 36
  6.1.2 Summary Statement of the Analysis ....................................................................... 37
  6.1.3 Methodology ............................................................................................................ 37
  6.1.4 Results ..................................................................................................................... 38
  6.1.5 Significance .............................................................................................................. 43
6.2 Product Risk Assessment .......................................................................................... 44
  6.2.1 Risk Identification .................................................................................................. 44
  6.2.2 Risk Heat Map ....................................................................................................... 46
  6.2.3 Risk Prioritization .................................................................................................. 46
7 Design Documentation .................................................................................................... 46
7.1 Performance Goals ..................................................................................................... 46
7.2 Working Prototype Demonstration .......................................................................... 47
  7.2.1 Performance Evaluation ......................................................................................... 47
  7.2.2 Working Prototype – Video Link ........................................................................... 47
  7.2.3 Working Prototype – Additional Photos ................................................................ 48
8 Discussion ....................................................................................................................... 53
8.1 Design for Manufacturing – Part Redesign for Injection Molding ....................... 53
  8.1.1 Draft Analysis Results ............................................................................................. 53
  8.1.2 Explanation of Design Changes ............................................................................ 54
8.2 Design for Usability – Effect of Impairments on Usability ......................................... 54

Page 3 of 65
8.2.1 Vision

8.2.2 Hearing

8.2.3 Physical

8.2.4 Language

8.2 Overall Experience

8.2.1 Does your final project result align with the initial project description?

8.2.2 Was the project more or less difficult than you had expected?

8.2.3 In what ways do you wish your final prototype would have performed better?

8.2.4 Was your group missing any critical information when you evaluated concepts?

8.2.5 Were there additional engineering analyses that could have helped guide your design?

8.2.6 How did you identify your most relevant codes and standards and how they influence revision of the design?

8.2.7 What ethical considerations (from the Engineering Ethics and Design for Environment seminar) are relevant to your device? How could these considerations be addressed?

8.2.8 On which part(s) of the design process should your group have spent more time? Which parts required less time?

8.2.9 Was there a task on your Gantt chart that was much harder than expected? Were there any that were much easier?

8.2.10 Was there a component of your prototype that was significantly easier or harder to make/assemble than you expected?

8.2.11 If your budget were increased to 10x its original amount, would your approach have changed? If so, in what specific ways?

8.2.12 If you were able to take the course again with the same project and group, what would you have done differently the second time around?

8.2.13 Were your team member’s skills complementary?

8.2.14 Was any needed skill missing from the group?

8.2.15 Has the project enhanced your design skills?

8.2.16 Would you now feel more comfortable accepting a design project assignment at a job?

8.2.17 Are there projects you would attempt now that you would not have attempted before?

Appendix A - CAD Models

Annotated Bibliography
LIST OF FIGURES

Figure 1: Two front views of magaritaville mixer and a detailed view of the removable bottles  ........8
Figure 2: Three isometric views of the Le Barmate ........................................................................... 9
Figure 3: Isometric view of Hamilton Beach Prime Pour and detailed view of pouring motion ........9
Figure 4: Drawing of front views of Automatic cocktail maker ......................................................... 10
Figure 5: Front view drawing of automatic cocktail machine .............................................................. 11
Figure 6: Function tree for Drink Mixer ............................................................................................ 23
Figure 7: Morphological chart for Drink Mixer .................................................................................. 24
Figure 8: Simple drawing of design 1 ............................................................................................... 25
Figure 9: Isometric and section view of Shaking and Stirring Machine ............................................ 26
Figure 10: Isometric view of Linear Arm Movement with detailed arm and stirrer mechanism ........27
Figure 11: Isometric view of no shaker and rotating plate with detailed spinning plate mechanism ...28
Figure 12: Simple drawing of concept 5 with complex mixing ........................................................... 29
Figure 13: Basic drawing of concept 6 with a plate that shakes and stirs .......................................... 30
Figure 14: Completed Concept Scoring Matrix .................................................................................. 31
Figure 15: Assembly of the drink mixer with labeled components .................................................. 33
Figure 16: CAD drawing of exploded view of the machine ............................................................... 36
Figure 17: SolidWorks back view of setup for motor torque kinematic analysis ............................... 38
Figure 18: SolidWorks front view of setup for motor torque kinematic analysis ............................ 38
Figure 19: SolidWorks close-up view of setup for motor torque kinematic analysis ....................... 38
Figure 20: Von Mises Stress analysis of shaker arm ......................................................................... 39
Figure 21: Von Mises Strain analysis of shaker arm ......................................................................... 39
Figure 22: Plot of the motor torque over time calculated from the SolidWorks analysis .................. 40
Figure 23: Page 1 of the hand done calculations for fluid flow .......................................................... 42
Figure 24: Page 2 of the hand done calculations for fluid flow - results at bottom of page ............. 42
Figure 25: The Moody Diagram, which was used to determine the friction factor (effect of pipe roughness and diameter on fluid flow) .................................................................................. 43
Figure 26: Before and After Images from of the shaker arm in SolidWorks ..................................... 43
Figure 27: Risk Assessment Heat Map ........................................................................................... 46
Figure 28: View of machine frame .................................................................................................... 48
Figure 29: View of shaker arm combination of the device ................................................................. 49
Figure 30: View of shaker arm, spring tube, and spinning plate ........................................................ 50
Figure 31: Image of a single container-valve combination ............................................................... 50
Figure 32: Image of entire container-valve-tubing combination ....................................................... 51
Figure 33: Image of spring and tube housing ..................................................................................... 52
Figure 34: Image of Arduino, relay, and motor controller setup ....................................................... 52
Figure 35: Before and after for draft analysis on the shaker arm ....................................................... 53
Figure 36: Before and after for draft analysis on the shaker arm ....................................................... 54
Figure 37: CAD drawing of the plate component of the machine ..................................................... 59
Figure 38: CAD drawing of the shaker arm component of the machine ........................................... 59
Figure 39: CAD drawing of the shaking disc component of the machine ......................................... 60
Figure 40: CAD drawing of the gabber component of the machine .................................................. 61
Figure 41: CAD drawing of the spring cap component of the machine ........................................... 62
Figure 42: CAD drawing of the pushing plate tube component ................................................................. 62
Figure 43: CAD drawing of the rear supported motor holder ................................................................. 63
Figure 44: CAD drawing of the front supported motor holder .............................................................. 63
Figure 45: CAD drawing of the body part for the machine. Structural supporting parts were modeled as part of the body. .......................................................................................................................... 64
LIST OF TABLES
Table 1: Interview data from customer interview ................................................................. 17
Table 2: Interpreted customer needs from interview table ..................................................... 20
Table 3: Target specifications of Drink Mixer ...................................................................... 22
Table 4: Bill of Materials ..................................................................................................... 34
Table 5: Parts list and costs ................................................................................................. 35
1 INTRODUCTION AND BACKGROUND INFORMATION

1.1 INITIAL PROJECT DESCRIPTION
Our group strives to create an automated drink dispenser and mixer. This device can take in different liquid ingredients, release a measured amount of each ingredient through solenoid valves, stir or shake the ingredients, and serve the beverage. The system can be controlled by pre-set buttons. The ingredients can be changed by the user each time the device is used. The device should be controlled by an Arduino that keeps the system running. Liquids should be able to be released and made into a complete drink within 15-20 seconds. The device should be sized to fit in a typical bar kitchen and able to be operated by a bartender to assist when restaurants are busy.

1.2 EXISTING PRODUCTS
Product 1: Margaritaville Mixed Drink Maker
Price: $1300
How to use: https://www.youtube.com/watch?v=Z15Bj4tAq3k

![Margaritaville Mixer](image)

Figure 1: Two front views of margaritaville mixer and a detailed view of the removable bottles

The Margaritaville Mixed Drink Maker is a simple machine capable of pouring 48 different mixed drinks. The product comes preprogrammed with these drinks, and includes a small user interface to select these from. The drinks can be slightly modified with a switch that increases their strength. The 4 liquids placed at the top are pre-set, and should not be modified (beyond the three acceptable liquors that can hold the first slot). The mixer is easy to set up and use. The machine only pours the drinks at the correct ratio, it does not chill or mix the drink to any extent.

Product 2: Le Barmate Infinite or One – blendbow
Price: 689 Euros (for an unstated number of months)

Figure 2: Three isometric views of the Le Barmate

Le Barmate Infinite is a high-end cocktail mixer that can take up to 8 different bottles of spirits, three different mixing liquids, mint, and limes/lemons as input. It comes preprogrammed with 100 cocktails but can be programmed to create up to 300 different recipes. It is self-cleaning, cools and mixes the drinks, is capable of quartering lemons or limes, and can crush ice. It is aimed at use by bars, as 4 cocktails a day at 8 euros would cover the cost of renting the machine.

Product 3: Hamilton Beach PrimePour Cocktails-On-Tap Cocktail Dispenser
Price: $4000 (This is according to several websites, although it seems entirely too high)

Figure 3: Isometric view of Hamilton Beach Prime Pour and detailed view of pouring motion
The CO2 powered PrimePour consistently produces one mixed drink on tap. It contains three bottles of alcohol (only one type of alcohol at a time – all three bottles are the same) along with a beverage mix of some sort and produces one mix ratio repeatedly. This is to allow the most popular drink at a bar to be produced quickly.

1.3 RELEVANT PATENTS
Patent 1: Automatic Cocktail Maker US 20110113967 A1

Figure 4: Drawing of front views of Automatic cocktail maker
This patent is very like the Margaritaville drink mixer. It only covers machines that simply pour out the correct proportions of several liquids into a glass. The patent includes reference to a programmable control unit that would allow the selection of drinks.


Figure 5: Front view drawing of automatic cocktail machine

This patent is also very similar to the other patent above. Mechanically it seems to work the same. However, instead of a vague programmable control unit, this patent refers to “flavor cards” that would be used when selecting one’s beverage of choice. A card with an image and name of the drink desired would be input and the machine would read it, and then output the drink. The card, assumedly, would be similar to an SD card of sorts or would contain some code that would indicate to the machine what cocktail to produce.

1.4 CODES & STANDARDS
NSF/ANSI 18 – 2016
NSF/ANSI 8 – 2012

1.5 PROJECT SCOPE
Purpose of product:

Our group strives to create a device that can take in different liquid ingredients, measure each ingredient according to a recipe, place the ingredients in a common container, add ice if necessary, stir or shake the ingredients, and serve the beverage. The device should have a user friendly interface that the user can access on the physical device and/or also on the phone. The device should be controlled by an Arduino that keeps the system running. The ingredients can be changed by the user each time the device is used. The device should be compact and able to be operated by a bartender to assist when restaurants are busy.
Customer:

- The product will be marketed towards bars or catering services.

Customer benefits:

- Easy access to more complicated mixed drinks, less cleanup, drink customization

Project goals:

Produce a machine that

- Can mix 3 drinks a minute with non-varying ratios
- Can add ice to the drink when made or served
- Can produce drinks that require shaking with ice
- Can accept at least 10 different ingredients
- Can be easily cleaned, and ingredients efficiently switched out
- Has a user-friendly interface

In-scope project accomplishments:

- We wish to produce a machine that can quickly and accurately produce bartender-quality drinks in a home or business setting.

Out of scope/thee project not accomplish these ideas:

- While it will not be made to replace bartenders, the device would help deal with busy shifts or periods of time when it wouldn’t be otherwise worthwhile to be serving drinks.
- The product will most likely be on par with other products on the market i.e. be expensive and not low-cost/accessible by many everyday consumers.
- As the product produced from this project will be a prototype, it will not include a perfectly user friendly interface that non-bartenders would be able to use.

Critical success factors:

- The product must be able to produce a drink within 30 seconds and with a specific accuracy.

Project assumptions:

- The machine will be able to handle plant matter or liquids high in acidity (such as lemon or lime). Failure to do this will lead to a dramatic drop in the number of drinks the product can make
- The machine will keep ice frozen. Failure would lead to warm drinks or harming the machine if the ice melts and then leaks into it.
• The machine will keep the cup closed while it shakes the beverage. Failure will lead to a leak in the beverage and the drink will be incomplete/make a mess.

The real-world limits for the project:

• Timeline: We have to have a working prototype before the week of Thanksgiving break (Nov. 20-24), this gives us approximately 10 weeks from today to research, model, buy equipment, assemble, test, and fix our prototype. This timing is very limited and may lead to difficulties in creating a finished product.

• Budget, we’ve been given a semester budget of $150. Competing products range from $800 on the low end to $1000s. These prices include varying cost from materials to labor, but also include profit so the product may not actually be that expensive to make, but we need to consider the best distribution of our funds.

• Staff: We only have 3 people working on this project during this course and we need to be able to communicate, create weekly goals, and ensure that the project moves along smoothly.

Key project deliverables:

• Research verifying code standards for producing beverages for consumption
• Research on materials and cost, finding the specific materials we are purchasing and keeping minute details on the budget usage
• Prototype of the liquid/ice input -- a completely mechanical input
• Prototype of the liquid/ice output -- this will require mechanization, such as pumps and motors
• Prototype of the stirring mechanism - motorized part that stirs the drink
• Prototype of the shaking mechanism - motorized part that seals the input cup and shakes it
1.7 **REALISTIC CONSTRAINTS**

Here, possible constraints on the product will be considered. A large range of technical and non-technical constraints will be examined in order to help refine the design.

1.7.1 **Functional**

One functional constraint that would be valuable to investigate is sizing of parts. The DM must be small enough to fit several easily in bars, and the materials used must be approved by standards listed previously. The kinematic systems to be used must function easily and smoothly as to not cause wear.

1.7.2 **Safety**

User and environmental safety is not a major constraint for the DM. The main concerns here are regarding the moving parts. It is theoretically possible that a user could catch their hand between the shaking mechanism and the hole through which it extends. To account for this, future iterations should cover this opening with soft plastic or a similar material. This will prevent a user from reaching somewhere dangerous.

1.7.3 **Quality**

In order to ethically sell this to bars, we need to make sure that all food standards are consistently followed for each unit. Otherwise, we risk harming users by tainting drinks, and therefore risking legal action. The design must also function over a long period of time in order to be worth the cost determined.

1.7.4 **Manufacturing**

We must determine before building that everything will fit together properly, and that it will be easy to assemble (although that somewhat falls under manufacturing constraints). The DM needs to be sturdy enough (and small enough) to safely ship in slight protective packing.

1.7.5 **Timing**

This project will most likely be bottlenecked at prototyping and production. This is due to the complexity of the shaking system. It is necessary that its longevity and efficacy are confirmed through multiple prototypes/testing.

1.7.6 **Economic**

As with any product, economic constraints are significant. In the case of the drink mixer (DM), the size of the market needs to be determined. While bartenders that were interviewed showed interest, it is important to discuss the product with bar and restaurant owners, as they would be the ones actually making the purchase.

Currently, the prototype cost has come out to approximately $200. This per unit cost will come down when large batches of DM's are produced, however, a cost this large would mean that the DM would cost a large amount. Research must be conducted to determine what amount a customer would be willing to pay for a DM, and this would thusly influence design.

1.7.7 **Ergonomic**

Cybernetic design is of importance for the DM. Interviewed bartenders stressed the importance of user interface simplicity for the sake of changing drink menus. The first prototype will only have pre-set
buttons, but future iterations will require a method for changing possible drink outputs. Controls will need to be clear and the layout should be as simple as possible.

1.7.8 Ecological
The only applicable ecological concerns would be those regarding power consumption and machine lifetime/recyclability. We want the machine to use as little power as possible, and it seems as though using only two motors and up to six solenoid valves will accomplish this. It is not a power intensive machine. However, we need to ensure that the machine does not break down quickly while being used. This would result in a short lifespan and the DM would be thrown away.

1.7.9 Aesthetic
Aesthetics may impact the sale of the DM depending on how a bar or restaurant desires to use the machine. If it is to be used behind a counter, out of sight of customers, it is not crucial that it is physically appealing. However, if a bars express interest in using the DM as a sort of gimmick, and displaying them as they run, then it is important that it is as sleek looking as possible, and that the shaking mechanism in particular is easily visible.

1.7.10 Life Cycle
Operational and maintenance constraints should impact the design of the DM. The DM contains many moving parts which will be under constant wear during use. This includes the stirring plate and the shaking arm armature. Maintenance will be needed to ensure these parts do not become too worn, and that any plastic lubricant used does not eventually become used up. It is also of upmost important that it is easy for the user to maintain the liquid distribution aspect of the machine. Particularly, it should be easily cleanable so that no health codes are broken due to mold developing.

1.7.11 Legal
The largest legal constraints on the DM are those imposed by the relevant Codes & Standards discussed in section 1.4. Specifically, constraints regarding the creation and serving of food products; essentially it is important that those that use this product are not made ill due to inappropriate materials or poor cleaning ability.

1.8 REVISED PROJECT DESCRIPTION
Our group strives to create an automated drink dispenser and mixer. This device can take in different liquid ingredients and ice, refrigerate each liquid and keep the ice frozen, release a measured amount of each ingredient, pump the ingredients in a common container, add ice if necessary, stir or shake the ingredients, and serve the beverage. The device should have a user friendly interface such as buttons or a touchscreen device for releasing liquids. The ingredients can be changed by the user each time the device is used. The device should be controlled by an arduino that keeps the system running. Liquids should be able to be released and made into a complete drink within 15-20 seconds. The device should be sized to fit in a typical bar kitchen and able to be operated by a bartender to assist when restaurants are busy.
## 2 CUSTOMER NEEDS & PRODUCT SPECIFICATIONS

### 2.1 CUSTOMER INTERVIEWS

Table 1: Interview data from customer interview

<table>
<thead>
<tr>
<th>Customer Data: Drink Mixer (DM)</th>
<th>Customer: Vance Baldwin (Bartender with 20 years experience in The Grove), Three Kings Bar Representative, Adam Ragwala (College Student Representative)</th>
<th>Date: 09/17/17</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Customer Statement</th>
<th>Interpreted Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Would you be interested in this product at all? /would your bar be interested in this product?</td>
<td>It sounds nice. As a bar owner, if you want to get tips, they want ways to get more money. It would be more feasible if it assigns a promotional drink for the night. If you have a higher business scale, it may be more efficient. If there’s less people coming through, it wouldn’t be useful since bartenders make tips off the client relationship.</td>
<td>DM serves people when there’s high traffic.</td>
<td>4</td>
</tr>
<tr>
<td>How many different types of drinks are ordered in a night?</td>
<td>Anywhere from 40-80. Depending on the bar. Some cap rooms have at least 100 beers on tap. Some restaurants have 4. There’s specific</td>
<td>DM serves many types of drinks</td>
<td>2</td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
<td>Score</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>How many ingredients are used in these drinks?</td>
<td>At least 2 key ingredients are used (base). Specialty drinks use 4 or 5 ingredients per drink. Not always common ingredients that can be repeated.</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>How long does it take to make a drink?</td>
<td>Probably less than a minute if the bartender knows and is on it. It should be less than a minute.</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>In what context would our product be used?</td>
<td>For shots, it'd be super great. So you can move onto something different and come back and grab it. If you have a row of main liquors, if you push the button, you get an espresso shot or two. You need a specific amount of liquor for many drinks. A lot of drinks of 4 1/2. So you can be more efficient for liquors. Common drinks are more useful so margaritas (3 ingredients). Basic vodka sprite, vodka soda. Lime juice versus squeezing.</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Do you care how it mixes the liquids? (Stirring vs shaking)</td>
<td>Stir and shake. Certain drinks are supposed to be shaken. Some chemicals can be bruised. Shaken needs</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

DM carries many ingredients per drink. DM serves one drink quickly DM is programmable DM carries lime juices.
<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Would you be interested in customers being able to use this/or bartenders?</td>
<td>/Would your interest increase if customers would be able to directly use these during high traffic nights? If they could put it on a table, it could help the business make more money. We’re trying to always work on efficiency and ease of service. If it’s an economical choice. DM makes easy drinks.</td>
<td>3</td>
</tr>
<tr>
<td>After all of these questions, do you think this product should be geared towards bars, or should we switch our customer basis?</td>
<td>He would recommend at home. There’s such a big base with person to person clientele in bars. There are already machine for guns with sodas, which makes it already easier for bars. It would be a harder switch for small bars. Our market would be more higher scale restaurants. It would be a party getter attention product. DM serves high scale restaurants. DM serves people at home who want to host small parties.</td>
<td>4</td>
</tr>
<tr>
<td>What kind of power source is acceptable? Compressed air vs electricity</td>
<td>Electricity is better. You have to make sure the cord is at least 10 feet long as not all bars have enough outlets DM should be wall plug powered and have a long cord</td>
<td>3</td>
</tr>
</tbody>
</table>
Would you be interested?

I would be interested if it were small and cost efficient.

DM is compact.
DM is cost efficient.

What kind of interface would be preferable? Touch screen or screen with pad?

If it lowers the cost, buttons. But if the touchscreen shows us the ingredients and the recipe, that would be preferable.

DM has buttons.
DM has a touchscreen interface.

2.2 INTERPRETED CUSTOMER NEEDS

Table 2: Interpreted customer needs from interview table

<table>
<thead>
<tr>
<th>Need Number</th>
<th>Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DM serves people when there’s high traffic.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Customer Needs &amp; Product Specifications</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------------</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>DM serves many drinks</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>DM carries many ingredients per drink</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>DM serves one drink quickly</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>DM is programmable</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>DM carries lime juices.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>DM stirs or shakes drinks accordingly.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>DM makes easy drinks</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>DM serves customers in larger businesses.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>DM serves high scale restaurants.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>DM serves people at home who want to host small parties.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>DM should be wall plug powered and have a long cord</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>DM is compact.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>DM is cost efficient.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>DM has buttons.</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>DM has a touchscreen interface.</td>
<td></td>
</tr>
</tbody>
</table>

### 2.3 TARGET SPECIFICATIONS
<table>
<thead>
<tr>
<th>Metric Number</th>
<th>Associated Needs</th>
<th>Metric</th>
<th>Units</th>
<th>Acceptable</th>
<th>Ideal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,2,9,10,11</td>
<td>Makes many drinks</td>
<td>Integer</td>
<td>6</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>3,6,8</td>
<td># ingredients carried</td>
<td>Integer</td>
<td>5 ingredients/drink</td>
<td>10 ingredients/drink</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>Dispensing Rate</td>
<td>oz</td>
<td>4 oz/push of a button</td>
<td>4.5oz/push</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>Stirs and shakes drinks</td>
<td>YES/NO</td>
<td>Y stirs/ N Shakes</td>
<td>Y Stirs and shakes</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>Avg time per drink</td>
<td>s</td>
<td>20s</td>
<td>15s</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>Power cord length</td>
<td>feet</td>
<td>&gt;10</td>
<td>&gt;20</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>Product cost</td>
<td>USD$</td>
<td>$300</td>
<td>&lt;$200</td>
</tr>
<tr>
<td>8</td>
<td>15,16</td>
<td>Simple, User friendly interface</td>
<td>Yes/No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
3  CONCEPT GENERATION

3.1  FUNCTIONAL DECOMPOSITION

Figure 6: Function tree for Drink Mixer
### 3.2 MORPHOLOGICAL CHART

![Morphological Chart for Drink Mixer](image)

Figure 7: Morphological chart for Drink Mixer
3.3 CONCEPT #1 – “NO SHAKING, SIMPLE DELIVERY AND MAKING”

Figure 8: Simple drawing of design 1

Description: This design variation is fairly simple and combines the needs for the drink mixer. The compartment on the top-right is a freezer for ice, and is removable for cleaning. The ice is fed into a hopper which deposits a consistent amount of ice into each drink. The design uses the bottles the liquids come in, which eliminates time designing separate canisters. The liquid delivery system is gravity fed, removing the need for pumps. The freezer and refrigeration unit use thermoelectric coils. A rod on an offset motor is used to stir, and can be raised and lowered by a rack and pinion. The conveyor moves the cup under each nozzle that is required for the drink, stopping while liquid is deposited. The machine does not shake. There is a touchscreen on the front face of the unit for selecting drinks. The arduino unit is located next to the interface.

Solutions:

1. Buttons w/ screen
2. Use bottles liquids come in
3. Attached ice bin
4. Gravity liquid
5. Hopper ice
6. Offset stirrer
7. No shaking
8. Conveyor belt
9. Thermoelectric cooling
3.4 CONCEPT #2 – “SHAKING AND STIRRING MACHINE”

Description: This version of the machine is a much more complicated version, opting for both mixing and stirring. The liquid is gravity fed, and stored at the top in non-removable sectioned containers. The containers are fairly wide to allow for cleaning. Ice is stored slightly behind them in a separate, non-removable container, and the ice is fed with a motor at the back, spinning it in. Both ice and liquid are dispensed from the same nozzle. Both are also cooled with separate thermoelectric cooling units. The shaking is done with a motor / cable / spring assembly. The motor spins, drawing the cable around itself and therefore pulling the platform holding the drink down into the spring. The motor then releases, allowing the spring to quickly push the drink back up. This emulates a shaking motion when done quickly. Stirring is accomplished by a motor with an offset stirring rod. This rod can be raised or lowered with a rack and pinion within the machine. The assembly fits in front of the dispensing nozzle (but is still above the cup. The machine is only compatible with special, sealable cups that can be closed if a drink requires shaking (must be closed before hand by user). The machine is operated with a small display screen with navigation buttons adjacent.

Solutions:

1. Display screen with separate buttons
2. Refillable but non-removable containers
3. Attached ice bin
4. Gravity fed liquid
5. Motor fed ice
6. Combined delivery
7. Thermoelectric cooling and freezing
8. Offset stirrer
9. Motor/cable/spring shaker
3.5 CONCEPT #3 – “LINEAR ARM MOVEMENT”

Figure 10: Isometric view of Linear Arm Movement with detailed arm and stirrer mechanism

Description: This machine incorporates various needs for the drink mixer. This machine has a separate compartment for the freezer and the ingredients. The compartment on top has an ice freezer and releases the ice through a nozzle by gravity. In a cabinet, there are containers that can be cleaned and interchanged. These containers are connected to tubes, which all feed into one nozzle next to the ice nozzle. The container section of the cabinet is refrigerated. A cup in the middle of the machine is held by a grip arm and it moves linearly along a horizontal path to get ice, get the liquid ingredients, and to go under the stirrer and be stirred when needed. The arm grip also moves vertically along one path. The cup gets a lid placed on it and the cup closes then the arm moves up and down vertically to shake the drink. There is a touchscreen interface on the front face of the machine to set a recipe. The controller and arduino unit of the machine is located in the bottom cabinet to the side.

Solutions:
1. Touchscreen
2. Refillable/removable liquid containers
3. Attached ice bin
4. Pump liquids
5. Gravity fed ice
6. Separate delivery
7. Linear track (arm)
8. Combined thermoelectric cooling
9. Thermoelectric freezing
10. Offset spoon/stirrer
11. Rack and pinion shaker (combined with arm)
3.6 CONCEPT #4 – “NO SHAKER, ROTATING PLATE”

![Isometric view of no shaker and rotating plate with detailed spinning plate mechanism](image)

**Figure 11:** Isometric view of no shaker and rotating plate with detailed spinning plate mechanism

**Description:** This machine incorporates various needs for the drink mixer. This machine has a separate compartment for the freezer and the ingredients. The compartment on top has an ice freezer and releases the ice through a nozzle by gravity. In the side cabinet, there are containers that can be cleaned and interchanged. These containers are connected to tubes, which all feed into one nozzle next to the ice nozzle. The freezer and refrigerated containers are kept cool by cooling coils. A cup in the middle of the machine is held on a spinning plate. The plate spins the cup under the ice and ingredient nozzles. The plate spins to stir the drink. The machine does not shake. There is a touchscreen interface on the front face of the machine to set a recipe. The controller and arduino unit of the machine is located on top next to the freezer.

**Solutions:**
1. Touchscreen
2. Removable/refillable containers
3. Attached ice pin
4. Pump liquids
5. Gravity fed ice
6. Spinning plate to stir
7. No shaking
8. Separate deliveries (spins to various nozzles/tools)
9. Cooling coils for both freezer and refrigerator
3.7 CONCEPT #5 – COMPLEX STIRRING AND SHAKING

Figure 12: Simple drawing of concept 5 with complex mixing

Description: The machine accounts for all delivery needs in the simplest ways possible, while the mixing components are fairly complex. All materials are gravity fed through the same delivery nozzle. Liquids are dispensed by electric powered valves, while the ice is released by a small latch operated by a motor. The machine opts to stir the drink by stirs it by gently spinning the cup. The liquid can also be shaken by an oscillating armature that the cup is inserted into. A cap is lowered from above using a spring to ensure no liquid is spilled. The liquid containers are removable for easy cleaning, and sit around the insulated, attached ice container. Both cooled sections are cooled using thermoelectric cooling units attached at the back of the machine. The machine is compatible with all bar glassware.

Solutions:

10. Touchscreen
11. Removable liquid containers
12. Attached Ice bin
13. Gravity fed liquids
14. Gravity fed ice
15. Combined delivery
16. Thermoelectric cooling
17. Thermoelectric freezing
18. Cup spinning stirrer
19. Armature Shaker
3.8 CONCEPT #6 – SHAKING ROTATING PLATE

Figure 13: Basic drawing of concept 6 with a plate that shakes and stirs

Description: This design variation combines the needs for the drink mixer. The compartment on the top-front is a freezer for ice, and is removable for cleaning. The design uses custom, removable canisters for liquids. The liquid and ice delivery systems are gravity fed, removing the need for pumps and a hopper. The freezer and refrigeration unit use cooling coils. All liquids and ice are deposited in the same location. The plate the cup sits on rotates in order to mix the liquids. A bar offset to a motor moves up and down shaking the plate and the drink. There is a touchscreen on the front face of the unit for selecting drinks. The arduino unit is located next to the interface.

Solutions:

1. Buttons w/ screen
2. Custom removable canisters
3. Removable ice bin
4. Gravity fed liquid and ice
5. Spinning plate mixer
6. Offset spin shaker
7. Cooling coils for refrigeration and freezing
8. Combined delivery
4 CONCEPT SELECTION

![Figure 14: Completed Concept Scoring Matrix](image)

4.1 EXPLANATION OF WINNING CONCEPT SCORES

Our winning concept (#5 in the chart) is one with fairly simple liquid and ice delivery methods, but with all encompassing methods of mixing. This mixing ability was weighted fairly highly; the fact that this design scored highly in that category, combined with the fact that its methods of mixing did not make it tremendously more difficult to manufacture is the primary reason it won. The design also scored well in cleaning and reliability, as most of the components are designed to be easily removable, also making them easy to clean. The design is compact, comfortably fitting within a 2x2x3 foot space, and none of the components were extravagantly expensive (as can be seen in the final purchasing chart). All designs scored similarly in programmability and ease of use, as all designs were somewhat derivative of each other in those categories. However, this design did have a slight edge in ease of use due to the easy removal of the various components.

4.2 EXPLANATION OF SECOND-PLACE CONCEPT SCORES

Our second ranked design (#1 in the chart) was very similar to the top ranked design. The design had a relatively low score when it came to the shaking mechanism. This is due to the lid being incorporated into the shaker grip and would require very precise machining to ensure the liquid does not spill out while shaking occurs. It would also be more affordable than the other designs since there are few motors required for use and the liquids are gravity fed. This would also make the design relatively easy to manufacture compared to almost all of the other designs. Thus this design is more feasible and has a higher appeal than most other designs, falling short of the top design choice on only a few criteria.

4.3 EXPLANATION OF THIRD-PLACE CONCEPT SCORES

This concept (#3 in the chart) overall had a low score, but had some higher scores in some instances and lower scores. The higher scores were in programmability, mixing ability, and reliability. This programmability rank came generally from the fact that liquid does not have to be pumped and can be released with a valve using an Arduino. This concept can shake and stir, which are both desired for the
final product. This product would be considered reliable because there are less removable parts and complex parts. The liquid containers and ice bin are not removable, which means they do not have to be replaced. Although it scored high in these categories, the total score was low due to low scores for the ease of manufacture, size, affordability, cleaning, and market appeal. Because the containers are not removable, someone has to go into the small spaces to clean them. The product is more expensive because there’s more moving parts such as the spring, cable, and stirring stick. In terms of market appeal, the product’s complex system and the difficulty to clean it makes it less user friendly, contributing to its lower score overall.

4.4 SUMMARY OF EVALUATION RESULTS
Overall, the concept selection process lead to the selection of a design that reflected a balance between simple methods of liquid delivery, but more complicated mixing systems. This is because great value was placed on the ability of the machine to mix – while this conflicts somewhat with the interviews conducted, the more complex mechanical system further increased the uniqueness and appeal of the design. However, we believe that these more complex systems were designed in the most compact and efficient way possible.
5 EMBODIMENT & FABRICATION PLAN

5.1 ISOMETRIC DRAWING WITH BILL OF MATERIALS

Figure 15: Assembly of the drink mixer with labeled components
### Table 4: Bill of Materials

<table>
<thead>
<tr>
<th></th>
<th>Name</th>
<th>Part no. / fab. Method</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drink Mixer Body</td>
<td>N/A (we will make)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Motor</td>
<td>N/A (from closet)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Shaker Disk</td>
<td>3D Printed</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Shaker Arm</td>
<td>3D Printed</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Grabber</td>
<td>3D Printed</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Bearing</td>
<td>N/A (from closet)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Stirring Plate</td>
<td>3D Printed</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Liquid Bottles</td>
<td>B01C1X443W</td>
<td>Amazon</td>
</tr>
<tr>
<td>9</td>
<td>Sealer Bearing Cap</td>
<td>3D Printed</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Compression Spring</td>
<td>9620K57</td>
<td>McMaster Carr</td>
</tr>
<tr>
<td>11</td>
<td>Sealing Plate</td>
<td>3D Printed</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Sealing Plate Cap</td>
<td>3D Printed</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Valves and tubing not pictured</th>
<th></th>
</tr>
</thead>
</table>

Valves and tubing not pictured: Found in table
Table 5: Parts list and costs

<table>
<thead>
<tr>
<th></th>
<th>Part</th>
<th>Source Link</th>
<th>Supplier Part Number</th>
<th>Color, TPI, other part IDs</th>
<th>Unit price</th>
<th>Tax ($0.00 if tax exemption applied)</th>
<th>Shipping</th>
<th>Quantity</th>
<th>Total price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12 OZ LONG RING NECK CLEAR PLASTIC DRESSING BOTTLE CASE OF 10</td>
<td>Amazon</td>
<td>B01C1X443W</td>
<td>Clear Plastic</td>
<td>$14.99</td>
<td>$0.00</td>
<td>$0.00</td>
<td>1</td>
<td>$14.99</td>
</tr>
<tr>
<td>2</td>
<td>Rubber Sheet, Heavy Duty, High Grade 60A</td>
<td>Amazon</td>
<td>RSBLK12x12x116-0-01</td>
<td>Black</td>
<td>$11.86</td>
<td>$1.19</td>
<td>$0.00</td>
<td>1</td>
<td>$13.05</td>
</tr>
<tr>
<td>3</td>
<td>Plastic Water Solenoid Valve - 12V - 1/2&quot;</td>
<td>Adafruit</td>
<td>997</td>
<td>White/Black</td>
<td>$6.95</td>
<td>$0.00</td>
<td>$9.16</td>
<td>6</td>
<td>$50.86</td>
</tr>
<tr>
<td>4</td>
<td>3M VHB Tape RP25 1in w x 5yd length</td>
<td>Amazon</td>
<td>1-5-RP25</td>
<td>White</td>
<td>$10.73</td>
<td>$0.00</td>
<td>$0.00</td>
<td>1</td>
<td>$10.73</td>
</tr>
<tr>
<td>5</td>
<td>HUAHA 10 pcs O.D. 1/4&quot; 3 Ways Shaped Tube</td>
<td>Amazon</td>
<td>HUAHA-TCT001</td>
<td>White Ts</td>
<td>$10.99</td>
<td>$0.72</td>
<td>$0.00</td>
<td>1</td>
<td>$11.71</td>
</tr>
<tr>
<td>6</td>
<td>Spring Tempered Compression Spring</td>
<td>McMast er Carr</td>
<td>9620K57</td>
<td>Steel</td>
<td>$5.63</td>
<td>$0.00</td>
<td>$12.00</td>
<td>1</td>
<td>$17.63</td>
</tr>
<tr>
<td>7</td>
<td>10 Pack - CleverDelights Solid Rubber Stoppers - Size 8</td>
<td>Amazon</td>
<td>RS-Black-8-10</td>
<td>Black rubber</td>
<td>$13.88</td>
<td>$0.00</td>
<td>$0.00</td>
<td>1</td>
<td>$13.88</td>
</tr>
<tr>
<td>8</td>
<td>Valve Adapter</td>
<td>McMast er Carr</td>
<td>5346K46</td>
<td>Brass</td>
<td>$8.02</td>
<td>$0.00</td>
<td>$0.00</td>
<td>2</td>
<td>$16.04</td>
</tr>
<tr>
<td>9</td>
<td>Press Fit Inserts</td>
<td>McMast er</td>
<td>97191A150</td>
<td>Steel</td>
<td>$8.83</td>
<td>$0.00</td>
<td>$0.00</td>
<td>1</td>
<td>$8.83</td>
</tr>
<tr>
<td>10</td>
<td>Set Screws</td>
<td>McMast er</td>
<td>97705A406</td>
<td>Steel</td>
<td>$2.73</td>
<td>$0.00</td>
<td>$0.00</td>
<td>1</td>
<td>$2.73</td>
</tr>
<tr>
<td>11</td>
<td>Elegoo UNO Project Basic Starter Kit</td>
<td>Amazon</td>
<td>EL-CB-001</td>
<td>Black</td>
<td>$13.95</td>
<td>$0.00</td>
<td>$0.00</td>
<td>1</td>
<td>$13.95</td>
</tr>
<tr>
<td>12</td>
<td>Speaker Wire</td>
<td>Amazon</td>
<td>B006LW0WDQ</td>
<td>Red</td>
<td>$8.49</td>
<td>$0.00</td>
<td>$0.00</td>
<td>1</td>
<td>$8.49</td>
</tr>
<tr>
<td>13</td>
<td>U Brackets</td>
<td>McMast er Carr</td>
<td>3192T55</td>
<td>White</td>
<td>$7.63</td>
<td>$0.00</td>
<td>$0.00</td>
<td>1</td>
<td>$7.63</td>
</tr>
<tr>
<td>14</td>
<td>Motor Control</td>
<td>Pololu</td>
<td>3284</td>
<td>red</td>
<td>$69.95</td>
<td>$3.95</td>
<td>$0.00</td>
<td>1</td>
<td>$73.90</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$264.4</td>
</tr>
</tbody>
</table>

Page 35 of 65
6  ENGINEERING ANALYSIS

6.1  ENGINEERING ANALYSIS RESULTS

6.1.1  Motivation
When reviewing our product, we reviewed codes such as NSF/ANSI 18 – 2016 and NSF/ANSI 8 – 2012. These codes summarize the types of materials and safety precautions we need to take when handling beverages for consumption. Most of the code standards specify that we need rounded edges in any equipment carrying food and beverages. When deciding on our design, the food handling processes were taken into account, but also the mechanical aspects and the functionality of them were analyzed. We want to consider the functionality of these aspects because it is often known that without proper testing, materials and designs can fail during its use. At times they can cause problems in the device and the entire device can fail. We want to
strive to test thoroughly and analyze our parts to ensure they’re properly designed before material and time is wasted to make faulty equipment. We want to make sure we handle the liquid ingredients with care, but also ensure the customer is receiving what they invested in. Thus, the ingredients released need to dispense the correct amounts. We anticipate to learn about how our motors and the pieces attached to them in our design run and if changes to the design of the objects can strengthen them or make them better for the overall design. We also hope to learn how the material of tubing and the attachment of different equipment affect the flow of the liquid ingredients and how that process can be best designed for our application to ensure our product runs smoothly and error-free.

6.1.2 Summary Statement of the Analysis
For our engineering analysis, we decided to determine the fluid flow rates in the piping used, the maximum stress and deformation of the shaker arm, and the maximum torque required by the motor. The fluid analysis was needed in order to determine how long the valves needed to remain open to release the correct amount of liquid. This fluid analysis will consider major and minor losses such as the tubing material, the length of it, and the turns and valves in the system. The maximum stress and deformation of the shaker arm was determined in order to ensure the arm does not break or undergo large strains during testing. This will help determine if the design needs to be adjusted before production and better speed up the testing phases. The maximum torque required by the motor was necessary to determine what motor would be used to run the shaker arm in the prototype.

6.1.3 Methodology
The stress and deformation of the shaker arm was calculated by first determining the maximum force on the end of the arm. This was done with a kinematic analysis combining the force of the cup holder and the acceleration of the mass of the water. The equations and calculations for this are written below.

Weight of 12oz of Water = .75 lbs

Acceleration (a) on shaker arm = 26.2 in/s² * (1ft/12in) = 2.18 ft/s²

Force on shaker arm (F) = 2.18 ft/s² * .75lbs = 1.635 lbsm *(1lbf/32.2 lbfm/ft *s²) = 0.0507 lbf

Total force on shaker arm (F) = 0.0507 + .75 = .8007 lbf

This data was then put into a SolidWorks study to determine the Von Mises stresses and displacements on the arm, based on it being made from ABS plastic. Two sliding fixtures were set at the end and the center pivot point of the shaker arm and the total force was placed on the end of the shaker arm that connects to the grabber claw. A medium mesh was set and we ran the simulation. The motor torque was also calculated using kinematic analysis in SolidWorks. Images of the SolidWorks setup are shown below. The motor torque was calculated on the mounted arm highlighted in the third image.
For fluid flow, the extended Bernoulli equation was applied across the valves to determine how long the fluid would take to flow through them. This number will be the length of time the arduino must hold each valve open. It will also act as an indicator of how long the drink will take to pour. It will not take into account the length of tube after the valve, so if the time to go past the valve is large, it can be extrapolated that the time after the valve is even longer (more tubing and more minor losses from obstructions). This analysis will be done by hand and the math is shown in figure 38 and 39.

6.1.4 Results

The following two figures show the results from the Von Mises simulation on the shaker arm. As seen in both figures, there’s a significant amount of deformation along the connecting face to the grabber claw. The highest amount of stress, is 64.8 psi along the edge of the connector to the grabber claw. The largest strain is .02315 mm. These results make sense for our application. The force we’re applying is relatively small and it does have an impact on our materials. After repeated use, these deformations would come into effect. The tensile strength
of the material, ABS, is 4351.1 psi, which is well above the highest amount of stress on the shaker arm, indicating that it shouldn’t break under the conditions we have set for our prototype.

Figure 20: Von Mises Stress analysis of shaker arm

Figure 21: Von Mises Strain analysis of shaker arm
The following plot shows the results of the motor torque study.

![Motor Torque vs Time](image)

**Figure 22:** Plot of the motor torque over time calculated from the SolidWorks analysis

With the maximum torque observed being 0.82 lbf-in. The motor torque was expected to change over time since the offset radius and force were changing with time as well, so only the maximum torque was considered.

**For Fluid Flow:**
**Extended Bernoulli Equation**

\[ p_1 + \frac{1}{2} \rho V_1^2 + \rho g z_1 = p_2 + \frac{1}{2} \rho V_2^2 + \rho g z_2 + h_{\text{major}} + h_{\text{minor}} \]

\[ \text{molar and minor losses} \]

\[ D = 0.25 \text{ inches} \rightarrow 0.00635 \]
\[ h = 3 \text{ inches} \rightarrow 0.0762 \text{ m} \]
\[ l = 5 \text{ inches} \rightarrow 0.127 \text{ m} \]
\[ l_2 = 3 \text{ inches} \rightarrow 0.0762 \text{ m} \]
\[ l_3 = 5 \text{ inches} \rightarrow 0.127 \text{ m} \]

0 and 2 are T joints which lead to minor losses.

\[ K_{\text{w1}} = 0.69 \]
\[ K_{\text{w2}} = 0.05 \]

**Across Valve**

\[ P_2 = P_1 = 0 \]
\[ V_1 = 0 \]
\[ z_1 = h \]
\[ V_2 = 0 \]

\[ \rho g h = \frac{1}{2} \rho V_2^2 + K_{\text{w2}} \frac{V_2^2}{2g} \]

\[ V_2 = \sqrt{\frac{\rho g h}{\frac{1}{2} \rho + \frac{V_2^2}{2g}}} \]

will find \( V_2 \), then take time to cross valve as average velocity between 0 m/s and \( V_2 \). (Assume water)

\[ V_2 = \sqrt{\frac{1000 \times 9.8 \times 0.00635}{\frac{1}{2} \times 1000 + \frac{0.00635^2}{2 \times 9.8}}} \rightarrow V_2 = 1.222 \text{ m/s} \]

\[ V_{\text{avg}} = \frac{V_2 \cdot V_1}{2} \rightarrow V_{\text{avg}} = 0.611 \text{ m/s} \]
The hand done calculations above reveal that the time it takes for 1.5 fl oz of fluid to flow out of the reservoirs and past the valve is 2.2 seconds. This seems to line up with the slight amount of physical experimentation done with the valve. The moody chart (shown below) was used in this calculation.
Figure 25: The Moody Diagram, which was used to determine the friction factor (effect of pipe roughness and diameter on fluid flow).

6.1.5 Significance

Based on the fluid flow analysis

Based on the stress and deformation analysis, chamfers were added to the shaker arm at the corners as shown below. This would help to dissipate the stress concentration that was found at the corners and further improve the strength of the part, which is under more stress than any other part of the prototype.

Figure 26: Before and After Images from of the shaker arm in SolidWorks

Based on the motor torque analysis, the motors we had planned to use were sufficient for the application, so no changes were made to those.
The fluid flow analysis is significant because 2.2 seconds is a fairly long time for just opening the valve. This time only accounts for one valve, and only for the flow past the valve. Given that there is much more pipe and T-connectors after the valve, the amount of time to actually get to the cup will be even greater. 2.2 seconds just signifies the amount of time that the valve must be held open by the arduino. Overall, this section indicates that the use of larger diameter tubing is most likely prudent.

Our results support moving forward with our prototype after implementing the above changes in order to improve the strength and flow rates of the design.

### 6.2 PRODUCT RISK ASSESSMENT

#### 6.2.1 Risk Identification

**Risk 1:** Shaking Bar hits/pinches user:

If the user puts their hand near the machine while the shaker is working, it is possible that their hand could be pinched between the mixer and the shaker. This is more likely if the user is intoxicated, but as the user should be a bartender, hopefully this will not be the case.

Impact: 3, Moderate: This could mildly injure the user. The force is not large enough to be seriously harmful, but it still would be surprising and hurt the machine’s reputation moving forward.

Likelihood: 2, Low-Medium: The user should be trained as a bartender. In addition there is no reason for the user’s hand to be in a dangerous position when it starts as well. Therefore, it is not very likely, but could still happen.

**Risk 2:** Excessively Alcoholic Drinks

If the valve leaks or the arduino incorrectly holds the valve open for too long, the drink may contain too much alcohol. This may become more likely over time as valves age.

Impact: 4, Significant: This could lead to undesirable drinks, which will hurt business, or it could lead to excessive, unexpected intoxication. Both of these can be very damaging to a business.

Likelihood: 1, Low: The programming of the arduino would have to be changed in order for it to give incorrect instructions to the valve. If the valve were leaking, that would be a much more apparent problem, which is covered in a later risk assessment. The valves have broken before but it was much more dramatic.

**Risk 3:** Property Damage

Valves may break, resulting in the leaking of liquids inside of the mixer, or outside. This may happen after extended use.

Impact: 4, Significant: This may result in the damaging or destruction of the drink mixer. It could also lead to property damage in the bar.
Likelihood: 3, Medium: Valves have broken before, and they are the only part of the machine that is used every time it runs (other than the arduino).

**Risk 4: Spilled Cup**

The cup can be somewhat difficult to remove, so some liquid may be spilled as it is taken out.

Impact: 2, Mild

If catastrophic, the liquid could be spilled on the bartender, causing some personal discomfort. It may also come in contact with other electronics in the bar, doing damage to them. However, spills happen in bars already, so this would not be adding too much risk for them. The spill would have to be catastrophic for it to be impactful.

Likelihood: 2, Low-Medium

The bartenders are the ones using this device, and therefore should be used to/ trained in its use.

**Risk 5: Interior Spillage**

While operating, the user will occasionally need to replace the interior liquids. This may occur given how narrow reservoirs are.

Impact: 4, Significant

These concerns are fairly similar to the concerns expressed regarding valve leakage. There is a possibility that fluid would get on the electronics and damage or destroy them. It would also be a waste of inventory for the bar.

Likelihood: 2, Low-Medium

This is of fairly low likelihood as the users should be trained as bartenders, and therefore used to pouring liquid into somewhat small containers. However, the reservoirs are somewhat small, making it a little more difficult to fill easily.

**Risk 6: Shaker Arm Breaks**

After repeated using, the shaker armature may break, spilling liquid and damaging other equipment.

Impact: 5, Catastrophic

This would mean the destruction of a major function of the machine. It would no longer be able to shake drinks. In addition fluid may be spilled if the shaker arm breaks while in use.

Likelihood: 2, Low-Medium

The stress analyses show that the shaker arm is fairly unlikely to break given the stresses that it is under. There is only very slight deformation.
6.2.2  Risk Heat Map

Figure 27: Risk Assessment Heat Map

6.2.3  Risk Prioritization

7  DESIGN DOCUMENTATION

7.1  PERFORMANCE GOALS
1. Drink Mixer prototype can pour and mix 2 drinks per minute.
2. Drink Mixer prototype can hold six ingredients.
3. Drink Mixer prototype can make 2 different types of drinks.
4. Drink Mixer prototype can stir or shake beverages.
5. Drink Mixer prototype is controlled by pre-set buttons for each drink.
7.2 WORKING PROTOTYPE DEMONSTRATION

7.2.1 Performance Evaluation
We believe that the prototype accomplished 2 out of the 5 performance goals set. It was able to pour two different types of drinks, as the two buttons released different combinations of the three liquids. The fact that the buttons worked also enabled us to accomplish the last goal of operating the machine with preset buttons. However, the motors did not supply enough torque to be able to mix the drinks, and misalignments due to woodcutting resulted in the spinning plate being effectively useless. Therefore, we were unable to accomplish the two goals that involved mixing. Finally, due to misjudging the size of the bottles and valves, we were only able to fit three bottles into the mixer, not reaching our benchmark of six different ingredients.

7.2.2 Working Prototype – Video Link

https://youtu.be/z01jGhuWZg0
7.2.3 Working Prototype – Additional Photos

Figure 28: View of machine frame
Figure 29: View of shaker arm combination of the device
Figure 30: View of shaker arm, spring tube, and spinning plate

Figure 31: Image of a single container-valve combination
Figure 32: Image of entire container-valve-tubing combination
Figure 33: Image of spring and tube housing

Figure 34: Image of Arduino, relay, and motor controller setup
8 DISCUSSION

8.1 DESIGN FOR MANUFACTURING – PART REDESIGN FOR INJECTION MOLDING

8.1.1 Draft Analysis Results

None of the parts for the drink mixer should be done with injection molding. They are all fairly thick plastic parts of varying thickness, which is generally not preferred for that method of manufacture. The analysis, however, was still run on the shaking arm, and that is presented here:

![Figure 35: Before and after for draft analysis on the shaker arm.](image)

A roughly 3.15 degree chamfer was added to all of the walls of the shaker arm, with the base being the larger section. This was done through a lofted boss/boss. The hold perpendicular to the end of the body was also removed, as this kind of geometry is not particularly compatible with this method of manufacture. This would require the redesign of any parts interfacing with the shaker arm, as the geometry is no longer square.
8.1.2 Explanation of Design Changes

Although the body is actually made of wood, a more reasonable analysis was done on it in the same manner (with some modifications made beforehand to open the shape up more).

![Figure 36: Before and after for draft analysis on the shaker arm.](image)

The same changes were made to the body as the previous part. 2 degree drafts were added to every side that required them. This reveals that perhaps this is not the best process for this part, as the draft becomes incredibly apparent on the side thickness. This is due to the fact that the body is such a large piece. In addition to the added drafts, the bottom and top plates were removed in order to simplify the part slightly.

8.2 DESIGN FOR USABILITY – EFFECT OF IMPAIRMENTS ON USABILITY

8.2.1 Vision

For a person with a vision impairment, the only dilemma we can foresee with using the drink mixing device is the colors of the buttons being used and the colors of the liquids. If we had a button for every liquid ingredient and a person could not tell the difference between the liquids, then they wouldn’t know which one to pour. An easy solution to this would be to provide labels for all ingredients and drinks. For the buttons, a label above them listing the ingredient or drink they release could readily help those with a eye color problem. For those who find it hard to see in general or may not be able to read a label, perhaps buttons with braille alphabet on them or above them could help the device be more versatile and usable by more customers.

8.2.2 Hearing

There shouldn’t be a problem for customers with a hearing impairment trying to use the drink mixer. There’s no component of the system that requires sound in order to know that it is functioning. Once a button is pressed, the user can visually see that liquid is pouring into the cup and thereafter that it is shaking or stirring. Hearing impairment may have an impact on the perception of errors with the machine, however. It is possible that a motor or valve could be malfunctioning and making a small sound that would indicate it. Someone with hearing
impairment would have difficulty perceiving this, and therefore may attempt to use a broken machine, worsening the problem.

8.2.3 Physical
There may be some difficulty with these physical impairments when using the drink mixer. If a person is weak or has sharp pain when using their muscles, it may be hard at times to use the machine. The machine in its current state requires users to manually press a button to release the ingredients and perform a shaking or stirring mechanism. It also requires the user to input a cup into the system. When placing the cup in, the user has to put some force against the spring holding the cap closed in order to be able to place the cup under it. In order to refill the machine, a user would have to remove the top cover and lift some bottles to pour in the ingredients over the top into the bottles. An alternative to pushing actual buttons would be to have a touchscreen since there’s no use of force in that attempt.

8.2.4 Language
A language impairment could make it difficult for the user to know which drinks are being served. Above we stated that labels and braille could help those with visual impairments, but if a person does not speak English, the labels wouldn’t tell them anything about the drinks available. A solution for that would be to consider the audience and main customers and address if additional labels in other languages would be helpful.

8.2 OVERALL EXPERIENCE

8.2.1 Does your final project result align with the initial project description?
Over the course of the semester, our project statement and scope have evolved and changed. Our initial thoughts of the scope of the project have changed. The product we initially envisioned was a drink mixer that we could market to bars and people at home. The drink mixer would be versatile and would carry many different ingredients and make several different beverages. We also wanted to incorporate refrigerated components and an ice bin. We hoped to create a user friendly interface such as several buttons or a Bluetooth connection to a smart phone. After going through the processes of concept generation, choosing a winning concept, and going through various component design analysis, our project scope has narrowed and become more specific. We created a product that we only wanted to market to bars. We decided to incorporate mechanical components such as a stirring and shaking mechanism. Our user friendly interface became two pre-set buttons. We also were only able to make a few drinks and carry limited ingredients because of size constraints. Over the course, we narrowed our interests and focused on our consumer, bars, and helping bars make drinks faster.

8.2.2 Was the project more or less difficult than you had expected?
As with most design or construction projects, the it was more difficult than expected. In particular, the manufacture of the prototype took much more time than anticipated. This was due to the delay in ordering and receiving parts and the various components involved in our system. Although it may seem simple to build a frame, precise measurements and cuts needed to be made to ensure our internal components fit and worked well with one another. When mixing several different elements such as the 3D parts with the wooden frame, several problems arose such as small mistakes in the frame measurements that then affected how our shaking mechanism fit into the system. It was also difficult to fix our parts after because we were in a time crunch to build and test our prototype. The container and valves were also difficult to
assemble because the tubing, valves, and bottles all didn't fit well with one another and an entire structure had to be created to fit them together, making them large and limiting our ability to fit several containers in the frame. Additionally, our electronic components were hard to work with since we didn't have prior experience working with Arduinos and control boards. Creating code and making our products run was fairly easy with the help of various online tools, but troubleshooting was a difficult task when our Arduino fried and ruined our relay and motor control board. The process had many holes throughout, making it difficult to get through each obstacle we faced.

8.2.3 In what ways do you wish your final prototype would have performed better?
The main way in which the prototype could have better performed is with regards to its motors. The motors broke before the prototype demonstration due to an amperage overdraw. This meant that neither the shaking nor stirring mechanism were functioning. The mechanical linkages were all in place and seemed to be functioning, but could only be moved by hand.

We purchased a replacement motor control unit, and in the end, we were able to get the shaking mechanism to function, however, due to an error in woodworking, the stirring plate was misaligned and could not function properly. This could easily be fixed and tested with more time.

8.2.4 Was your group missing any critical information when you evaluated concepts?
Had we known we weren't going to incorporate refrigerated components initially, we most likely could have generated more concepts that aligned with our interests in holding several different ingredients, shaking the cup, stirring the cup, and using a machine-specific cup or making a machine that can use any cup. Having an initial idea of the budget and making a preliminary list of materials for our first concepts could have helped understand the mechanisms and components early on and could have better prepared us for choosing a concept that we could finish in time.

8.2.5 Were there additional engineering analyses that could have helped guide your design?
An analysis of the spring system would have been useful. In the end, we purchased several different strengths of spring and tested all of them. It would have been better had we used force balancing in order to determine what the proper strength of the spring should be.

8.2.6 How did you identify your most relevant codes and standards and how they influence revision of the design?
We identified our most relevant codes and standards to be those regarding the processing and serving of foods, as the DM directly deals with both of those. However, neither of these impacted the design of the prototype, as materials used in food processing are overly expensive for the scope of this project.

8.2.7 What ethical considerations (from the Engineering Ethics and Design for Environment seminar) are relevant to your device? How could these considerations be addressed?
Ethical concerns when building this device would be ensuring that this product is safe and can be used by people for some time. Something particularly important with our idea and concept would be the safe keeping of perishables and ensuring that the containers and the tubes deliver drinks safely to our consumers. Failures to keep safety measures can lead to people getting sick from their product, thus it's important to follow proper guidelines set for the handling of food and beverages.
8.2.8 On which part(s) of the design process should your group have spent more time? Which parts required less time?

In particular, the valving system should have been more thoroughly examined before purchasing parts. More appropriate solenoid valves should have been found, as the valves purchased had NPS threading, which does not fit with most readily available piping.

8.2.9 Was there a task on your Gantt chart that was much harder than expected? Were there any that were much easier?

By far, the hardest task was prototype construction. We failed to allot this task nearly enough time (as we did not take into account possible difficulties in construction), which lead to an extreme amount of work in a small span of time. Eventually, when the motor controller broke, we were unable to fix it, or purchase a new one, due to a lack of time. The early concept generation and selection tasks were generally much easier, requiring significantly less time than was given for them.

8.2.10 Was there a component of your prototype that was significantly easier or harder to make/assemble than you expected?

The frame itself was a lengthy process and needed precise measurements. Although the idea seemed easy to create a frame to put our components into, the design and measurements needed to be thought out to fit each piece and ensure that the right pieces end up fitting correctly with each other. We did put initial calculations into the creation of the frame, but the final product demonstrated how we could have been more careful in our design. The entire frame ended up being too small for our liquid ingredient containers and our tubing system. The mishaps in the measurements led to a misalignment of the spinning plate and the shaker arm. The thickness of the frame was not completely accounted for, which affected how far the shaker arm reached beyond it. The liquid containers and the tubing were also significantly harder to make. Our valves did not match the tubing and the containers. And entire system had to be fitted using several different parts, which slowed our flow rate and made the system more complicated and bulky than we initially expected. Printing our 3D parts was a fairly simple and easy task and we expected to sand a few pieces to fit them. The 3D printing of our parts was fast and convenient. The Arduino system did prove to be a difficult task because of the combination of running valves and motors, while setting them all to the control of a button.

8.2.11 If your budget were increased to 10x its original amount, would your approach have changed? If so, in what specific ways?

The many components in our project made it much more expensive than we thought it would cost. While we were building each system, we realized we were missing something and would have to go out each time to buy the right part to add. Had our budget been increased, we still would have gone over budget as we did this time. Our pieces were just incredibly expensive and the cost added up very quickly, even after we used motors and other parts from the basement and borrowed equipment from ASME. One motor controller board alone cost $60, which was more than one third of our budget. A conversation with our professors earlier on could have mitigated this. As stated above, creating an initial parts list with our concept generation could have led us to choosing a good concept that we could also afford to construct. Also, this conversation could have helped instructors set budgets accordingly and reviewed how the quantitative goals helped set could lead to more expenses.
8.2.12 If you were able to take the course again with the same project and group, what would you have done differently the second time around?

There are many approaches that could have been taken when going into this class. A good change to this course would be to go into the class more prepared. This class would run better if groups are formed before the first week of class so that the dynamic starts strong. The class started very slowly and picked up incredibly fast towards the end of the semester so the ability to spread out some of the slow parts before class officially starts could have been very beneficial. It would have been better to choose a concept at the end of junior year and get started with background studies and concept generation, so that once the semester starts, meetings with the professor can get the project started on a strong pace. Each system could have been designed, analyzed, and edited before parts are bought to create a thorough parts list. By starting earlier, there would be more time to fit things and test components and change them to work better together, which would have led to a better end product. Intermediate build checks and set deadlines would have ensured a better effort into the product.

8.2.13 Were your team member’s skills complementary?

To some extent, they were. Some members were able to work on the Arduino system while another built the frame and physical components. This allowed for fairly effective splitting of labor. However, there was very little prior knowledge of the Arduino system, so much of that time was spent learning how to assemble and operate the motor and valve control system.

8.2.14 Was any needed skill missing from the group?

No one in the group had prior knowledge of how to program or assemble Arduino systems. This was, however, fairly simple to learn how to do, though more time should have been set aside for this task.

8.2.15 Has the project enhanced your design skills?

Any time one goes through this entire process, their design skills are honed. Even if the process ends in failure, and even if one does not notice it, you are always learning slightly more about each step of the process each time you do it. In particular, the design process always reinforces the concept that prototype construction always takes longer than anticipated.

8.2.16 Would you now feel more comfortable accepting a design project assignment at a job?

To some extent yes. A single iteration of the design process does not make one perfectly adept at the job, but at the very least we are more familiar with certain terminology of the process. We are also now more aware of what is expected at different points along the way.

8.2.17 Are there projects you would attempt now that you would not have attempted before?

We’ve learned a lot more about different motor driven mechanisms, which has inspired us to take on design and build oriented clubs, research, or career paths. The introduction to using an Arduino was great and exciting. Arduinos are great tools and can be incredibly versatile. The programming of them was easy to pick up and their ability to control different systems showed the strength of the tool. The idea of going into robotics or mechatronics seems more feasible and incredibly interesting.

9 APPENDIX A - CAD MODELS
Figure 37: CAD drawing of the plate component of the machine

Figure 38: CAD drawing of the shaker arm component of the machine
Figure 39: CAD drawing of the shaking disc component of the machine
Figure 40: CAD drawing of the gabber component of the machine.
Figure 41: CAD drawing of the spring cap component of the machine

Figure 42: CAD drawing of the pushing plate tube component
Figure 43: CAD drawing of the rear supported motor holder

Figure 44: CAD drawing of the front supported motor holder
Figure 45: CAD drawing of the body part for the machine. Structural supporting parts were modeled as part of the body.
10 ANNOTATED BIBLIOGRAPHY


