AUTOMATED COCKTAIL MIXER PROPOSAL

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Project Proposal for ECE 445, Senior Design, Spring 2026
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February 2026
Project No. 9

Contents

1. Introduction

Here we will discuss our idea for a project. What the problem statement is, our solution, a visual aid to help give an image for what our product may look like and outline some requirements so we can quantitatively measure the performance of our cocktail maker.

1.1 Problem

Mixing cocktails and mocktails, whether at home or elsewhere, can sometimes be a difficult process. While even simple, two-ingredient cocktails exist, to have consistency when recreating them there must be precision and accuracy in measuring ingredients, and often these are liquid ingredients in small quantities, which can be easy to mess up. The average person may struggle to consistently mix drinks with the proper ingredient ratios without practice and jiggers or other measuring tools. This could lead to overpouring drinks which have more alcohol in them than expected, which can lead to overdrinking if not careful.

A solution to this issue lies in automating the process of measuring and mixing these drinks. Commercially available automated cocktail machines do exist presently, but the average consumer will almost certainly never adopt them due to high prices, ranging from several hundred to several thousands of dollars. Many of these products also require proprietary bottles or flavor pods, which limit usability and customization. There's a clear gap in the market for an affordable, compact, fully automated drink-mixing solution that doesn't rely on proprietary consumables and gives freedom to the user.

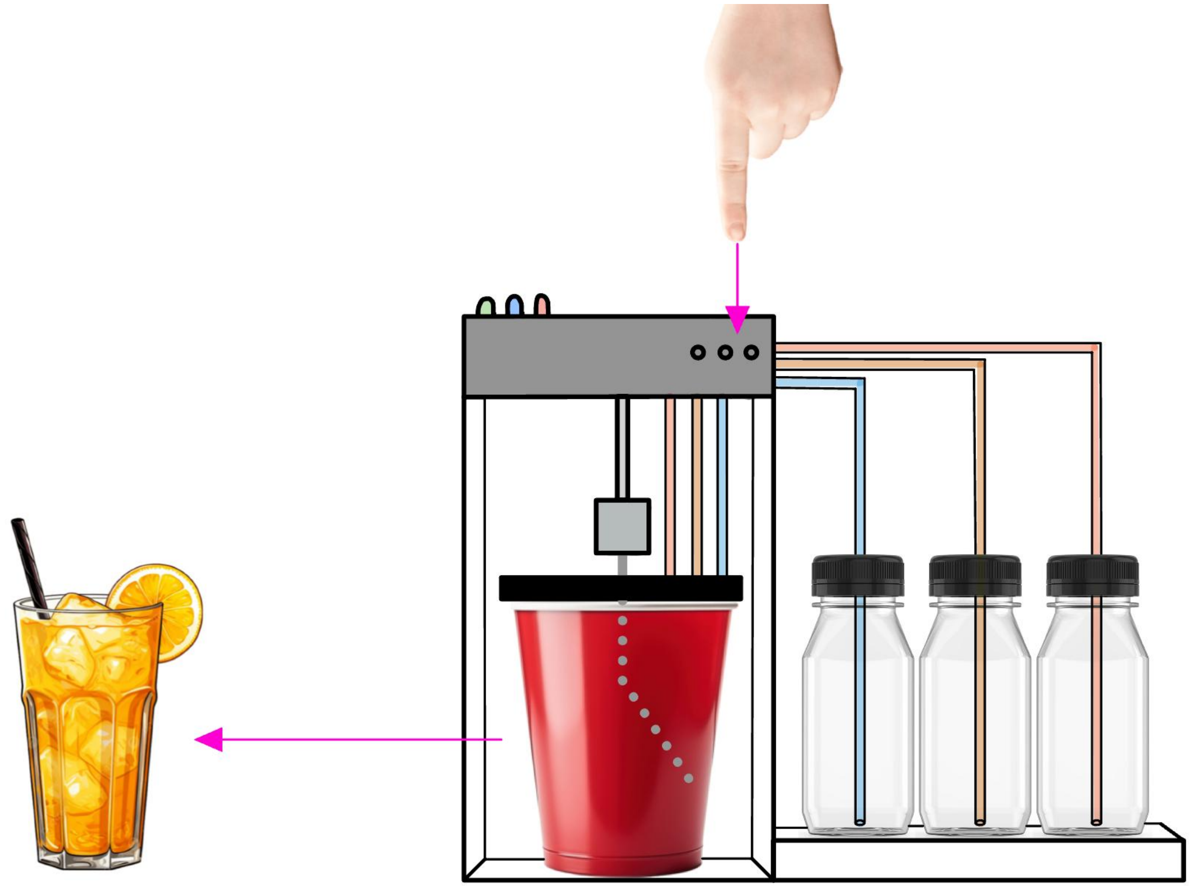
1.2 Solution

Our proposal centers on a cocktail and mocktail mixing machine controlled by a simple ESP32 microcontroller. The initial design for this system will allow the user to make their drink selection via a simple push-button input, verify the presence of a cup or glass via a weight sensor, then dispense the correct volume of each ingredient into the cup. After dispensing, an automatic stirring mechanism will lower itself into the cup, mix the drink, and then retract. LEDs will be used to communicate the status of the drink to the user, lighting up green once it is finished and lighting red if there is an issue.

The machine will be built around a central cup station with a load cell weight sensor underneath it. At least two liquid containers (cups or bottles) will be connected via vinyl tubing to individual peristaltic pumps for simplicity and accuracy. Each container will also sit on its own load cell to monitor liquid levels. When the user presses a button to select a drink, the microcontroller will first read the cup load cell to make sure there is a cup present. After reading the ingredient load cells to ensure there is enough to make the drink, the microcontroller will then activate the first pump, dispensing liquid while monitoring the load cell below the cup until the target weight for the recipe is reached. This process repeats for each ingredient in the recipe. Once all ingredients have been dispensed, a linear actuator motor will lower the stirring arm into the cup, and a second motor will rotate the stirrer for some length of time. The stirring arm will retract, and a green LED will turn on to signal that the mixing process has completed. If there are any issues at any point (no cup, not enough liquid) then a red LED will turn on.

The entire system will be housed in a compact and portable enclosure, targeting a low total cost that makes it affordable for the average consumer.

1.3 Visual Aid



1.4 High-level requirements

To solve our problem our cocktail maker must satisfy 3 conditions.

1. The cocktail maker must dispense each ingredient to within ±5 grams of the target weight/volume specified by the recipe, as measured by the load cell beneath the drink cup.
2. The cocktail maker must detect the presence of a cup (weight threshold of 50 g) and verify that there is sufficient liquid in each ingredient container (minimum weight required by recipe plus extra 20% margin) before beginning the mixing process, halting and turning on the red LED within 3 seconds if there are any issues.
3. The complete drink mixing cycle, from button press until the stirrer is retracted, should be completed in under 150 seconds for a standard two-ingredient recipe.

2 Design

In this section we will discuss the design of our cocktail. There will first be a block diagram mapping out our design and the different subsystem we will use. Then we will go into descriptions for each subsystem to explain how they work, how they interact with each other, and components they will use to achieve proper functionality. Then we will discuss requirements to explain what the expected performance of each subsystem is and to give more specifics on what is required of them. Lastly, we will discuss some tolerance analysis and other calculations we will do so that our cocktail machine works as intended.

2.1 Block Diagram

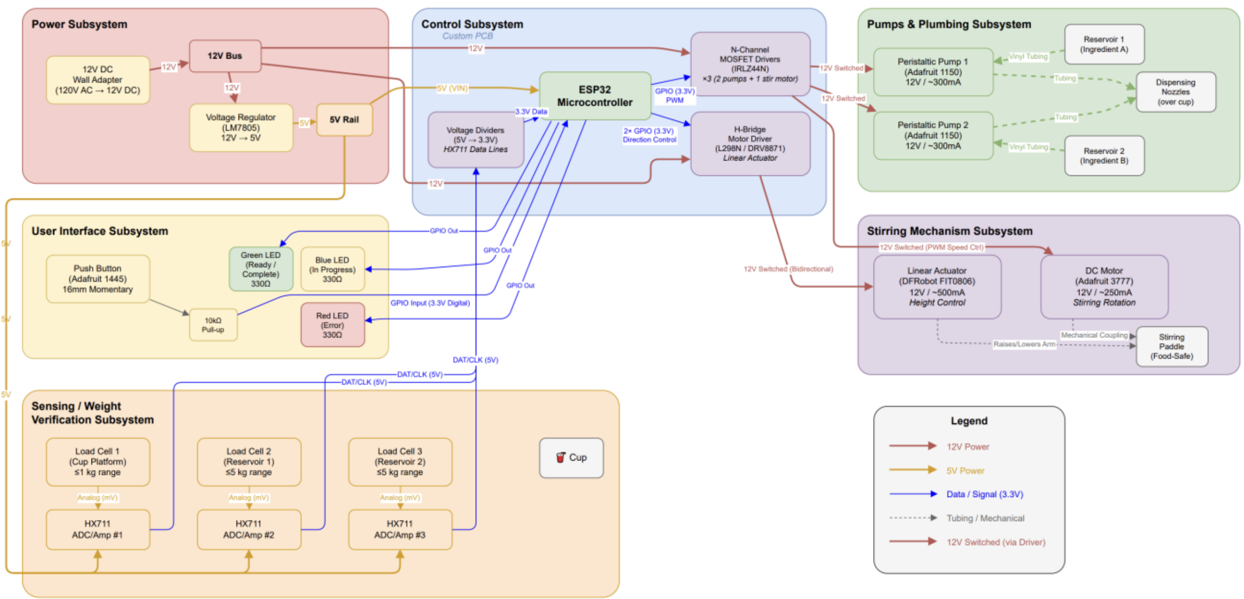


Figure 1: full system block diagram

2.2 Subsystem Descriptions

2.2.1 [User Interface]

For our user interface allowing the user to interact with the cocktail maker we will use a simple pushbutton that is hardcoded to a specific cocktail. Upon the user pressing this button, a signal will be sent to the microcontroller letting it know a drink has been requested. The microcontroller will then verify if a drink can be made. If so, the microcontroller will send a signal to the first pump to start working and the user's input of pressing the button will be successful and a cocktail will start being made. If verification is unsuccessful then a red LED will light up to notify failure and the user's input will have been unsuccessful.
For potential expansion we would add more pushbuttons that are hardcoded to make other cocktails. Eventually if all is working well and time permits, we will expand to a more complex user interface where the user would have a menu of sort to interact with.
Potential Products: 16mm Panel Mount Momentary Pushbutton - Red Product ID: 1445

2.2.2 [Stirring Mechanism]

Once all liquids are transported from the liquid housing containers into the glass the user will eventually drink from, the ingredients must be incorporated together in some way. To do this we

will make a stirring mechanism that has two different motors both of which are controlled by the microcontroller. The first motor (a linear actuator) will oversee the height of the arm that will be used to stir. The arm originally must be out of the way for the user to put the glass in. So, this motor will lower the stirring arm to be at an appropriate height to mix the liquids in the glass. The second motor (gear reduction motor) will rotate the stirring arm to perform the mixing process. The second motor will only turn on once it receives a signal from the microcontroller that the first motor has moved from its home up position to its working down position and is off. The height motor will only move in two scenarios. The first is the microcontroller sends a signal that all the ingredients have been successfully transported into the glass. The second condition is upon receiving a signal from the microcontroller that the stirring arm motor is done and the motor can now be raised again. These motors will also be connected our power system for the required voltage.
Potential Products: Dfrobot fit0806 (Height), Adafruit 3777 (Stirring) and associated drivers

2.2.3 [Pumps and Plumbing System]

We need a system to transport the ingredients from the liquid housing containers to the user's final glass. To do this we will use some clear tubing as plumbing to guide the liquids and pumps to control the flow of liquid from the housing to the final glass. The pumps will work one at a time in a sequential order only starting to dispense a liquid once the other has finished. The pumps will be connected to the microcontroller which will send start and stop signals based on how much liquid has been dispensed so far. The microcontroller will get the amount of liquid dispensed based on the values from weight sensors in the Status and Weight Verification System. Once reaching a threshold value, the microcontroller will tell the pump to turn off. The pumps themselves will be hooked up to our Power System to provide their required voltage.
For potential expansion we could add another pump and tubing with it to allow for cocktails with more than 2 ingredients.
Potential Products: 1/6 in. I.D. x 1/4 in. O.D. Clear Vinyl Tubing, Adafruit 1150

2.2.4 [Control Subsystem]

For all this transfer of data between our user input, the motors, the pumps, and our weight sensors, we need a microcontroller to control all this data and make use of the data our sensors and other devices are sending. The control system will interact with interact with all subsystems. It will first interact with the user interface to take in a user's request. It will then act with the status and weight verification system to see if the proper conditions are met for a drink. Depending on if they are met or not, one of the LEDs will turn on to either start making a drink or to notify that conditions were not met to make a drink. Assuming a drink can be made, the microcontroller will then communicate with the pumps and plumbing system to start and stop the dispersion of liquids from the housing containers to the user's glass. Then the microcontroller will communicate with the stirring mechanism to start the process of combining the elements in the drink. First it will force the hand to be lowered, then rotated, then raised again. Lastly, the microcontroller will send a signal to the status and weight verification subsystem once again letting the user know a drink was made. The control system is also connected to the power system to provide the required voltage.
Potential Products: ESP32 microcontroller, Custom PCB

2.2.5 [Status and Weight Verification System]

Before making a drink, we must know if certain criteria are met so we don't just start randomly dispensing liquid onto the counter. We also need some way to track how much liquid has been transferred from the liquid housing containers to the user's glass. Lastly, the user should know the state the cocktail maker is currently in to know if something is wrong, if the cocktail is made, or if the cocktail is in the process of being made. This is what the status and weight verification subsystem is for. This subsystem will consist of 3 LEDs (green, red, blue) and initially 3 weight sensors (1 for the user glass and 1 for each of the liquid housing containers). The green LED will be lit when a cocktail is properly made, the blue LED will be for when the cocktail is in progress of making a drink, and the red LED will be for when there is some sort of issue so a cocktail can't be properly made. No user input will be accepted if any of these LEDs are on. The weight verification sensors have multiple uses. The first thing is upon receiving a user input the microcontroller will check the values of the weight sensors. It will check the user glass weight sensor to make sure a glass is there to catch the liquids. It will also check the other weight sensors to make sure there is enough liquid in the containers for the requested drink. Then we use these weight sensors to make sure the correct amount of liquid is taken from the liquid housing containers and is dispensed into the user's glass by having these sensors communicate with each other through the microcontroller. We will also require an amplifier to be connected to each weight sensor for proper use. This subsystem will also be connected to our power system to supply all required voltages.
For potential expansion we could get extra weight sensors to allow for cocktails with more than 2 ingredients.
Potential Products: Adafruit 4540, Sparkfun tal220, Amplifier hx711, LEDs from machine shop.

2.2.6 [Power System]

The function of the Power System is to convert the AC wall power to the DC voltages required by the system. A 12V DC wall adapter will provide the primary supply, while an onboard voltage regulator will step this down to 5V for the sensor amplifiers and the ESP32 processor. The 12V rail will also directly power the pumps and motors through their respective driver circuits. This subsystem connects to every other subsystem.
Potential products: Tri-Mag L6R48-120

2.3 Subsystem Requirements

2.3.1 [User Interface]

The user interface subsystem allows the user to initiate the drink-mixing process and provides feedback on the system status. It interfaces with the control subsystem through GPIO.

- The green LED must light up when the system has successfully made a drink.
- The blue LED must light up when the system is actively making a drink.
- The red LED must light up whenever a fault is detected (no cup, not enough liquid, etc.)

2.3.2 [Stirring Mechanism]

The stirring mechanism subsystem automates the mixing of dispensed ingredients in the cup. It needs to lower the stirring paddle/spoon into the cup, rotate it, then retract it without spilling the drink.

- The linear actuator must provide at least 50 mm of vertical travel to move the stirring paddle from above the cup rim to near the bottom of the cup.
- The linear actuator must be able to be both extended and retracted via an H-bridge driver, timed by the microcontroller to prevent overextension.
- The rotary stirring motor must rotate the stirring paddle at a speed between 50-150 RPM to mix competently without splashing, specific RPM to be determined later.
- The stirring paddle must be made of food-safe material and small enough to fit in a standard cup.
- The stirring process in its entirety must complete within 30 seconds.

2.3.3 [Pumps and Plumbing System]

The pumps and plumbing subsystem is responsible for transporting liquid ingredients from the containers to the cup.

- Each pump must operate at 12V DC and deliver a flow rate of about 100 mL/min.
- Tubing must be easily removable for cleaning.

2.3.4 [Control Subsystem]

The control subsystem is the central processing unit that executes drink recipe logic, reads sensors, and drives the motors and pumps. It must be responsive and robust.

- The ESP32 must poll button input and read all weight HX711 channels at a rate of at least 10 samples per second.
- The PCB must include n-channel MOSFET driver circuits for each pump and for the rotary stirring motor, with gate resistors and pull-down resistors to prevent floating gates.
- The PCB must include an H-bridge driver with control inputs from two ESP32 GPIO pins for the linear actuator.

2.3.5 [Status and Weight Verification System]

The status and weight verification system provides feedback to the microcontroller system for precise ingredient dispensing and safety checks.

- The cup platform load cell must support about 1 kg to account for both a cup and up to 350 mL of liquid.
- The ingredient container load cells should have 5 kg capacity to support larger ingredient quantities.
- The cup detection threshold should be set at 50 g, and the system should have the capability to distinguish between an empty platform and the 50 g threshold.
- Each ingredient container load cell should be able to verify that the container contains at least 120% of the required ingredient weight.
- During dispensing, the microcontroller must read the cup load cell and the ingredient load cells to stop the pump within 5 g of the target weight.

2.3.6 [Power System]

The power subsystem provides all electrical energy to the system. It needs to deliver stable power at the correct voltages to ensure reliable operation of every component in the system, including the microcontroller, sensors, motors, and pumps.

- The 12V DC wall adapter must supply at least 3A of current to support the simultaneous operation of one pump, the linear actuator, the rotary motor, and overhead for the rest of the system.
- The 5V voltage regulator must supply at least 300 mA at 5V to power at least three HX711 amplifier boards and provide power to the ESP32 microcontroller.

2.4 Tolerance Analysis

2.4.1 [Proper Amount of Liquid Transferred]

The main source of external error that our design introduces that we must account for involves the pumping of ingredients from the liquid housing containers to the user glass. For example, let's say we want 100 mL of a specific liquid. We can't tell the pump to stop pumping when 100mL has been added to the user glass. If we do this then we will have some liquid that is still in the plumbing that will eventually end up in the drink due to gravity. To counteract this, we must send the signal for the pump to stop slightly before 100 mL has been added to the user glass. Therefore, we are accounting for the fact that extra liquid from the tubing will fall into the glass due to gravity. We will approach this problem in two ways. First, we will come up with a predictive equation that using variables listed below will let us know the volume we should stop dispensing to get our desired volume. We can also test this manually by, for example, stopping at 93 mL and seeing what we end this. We would perform this experiment many times to reduce variance.

$$F * t = V \tag{1}$$
$$L = D - V \tag{2}$$

With Variables:
- V ~ volume of post pump tubing
- F ~ flowrate [up to 100mL per minute]
- t ~ time
- L ~ coded weight sensor value which shuts the pumps off
- D ~ desired ingredient amounts

2.4.2 [Kink in Tubing]

Another source of external error is that because we are using plastic tubing, at times there may be kinks that prevent the liquid from properly being transported. There are two ways we could combat this. The first is to have a timer in the program for each pump with each drink that has a max limit. We know how much time it should take for the liquid to be transported so if after that much time plus a little extra for accommodation, if the correct amount of liquid has not been dispensed in the user glass, then the red LED will light up to signify an issue. While this issue works, if the pump time is expected to take a minute, if you have a kink at second 5 then the pump runs for about an entire minute before finally stopping. Another option would be to check the weight of the user glass at certain intervals to see if the expected progress in liquid transportation is being made. If not, then once again light up the red LED to signify something went wrong.

2.4.3 [Loss of Connection or Power]

Lastly, another source of external error is if something goes wrong with the machine losing power or the USB C of the microcontroller accidentally getting unplugged. If this were to happen at any process during the making of the drink, the drink should be scrapped and if another drink is wanted the process should start from square 1. To do this, if the blue LED is ever on and we lose power or connection, upon regaining power a flag bit will be set to turn on the red LED. This flag bit will only be cleared once the user glass is removed from the sensor as this would mean that the drink is scrapped.

3. Ethics, Safety, and Societal Impact

As soon to be engineers, we have the responsibility of designing systems which prioritize user safety, reliability, and responsible use. Thus, it is important we keep in mind and thoroughly evaluate our design to ensure that nothing might jeopardize these responsibilities.

3.1 Ethics

The first lens to look through when evaluating this design is an ethical one. The IEEE and ACM Codes of Ethics state that engineers should prioritize public safety and welfare, be honest about a systems limitation, avoid any deceptive practices, and have systems designed to minimize the risk of harm. Keeping all this in mind when reviewing the automated cocktail/mocktail makers design, there are two primary ethical responsibilities which stand out the most here.

Our first, and most obvious, ethical consideration is the responsible use of the product as it relates to its alcohol pouring abilities. While this system can dispense and mix alcoholic drinks, it should not promote any sort of unsafe or excessive consumption practices or misrepresent a drinks strength. To combat this, what our system will do is use weight sensors to measure out ingredients and effectively limit the amount of each liquid added to a cup within some defined tolerance. What this does is prevent any sort of accidental overpouring and can easily be tracked by documenting dispensing tolerances or accuracy. This sort of documentation, when all said and done, also provides users with a clear understanding of the system's limits so that they understand the measurements are approximate and should be treated as such.

The second main ethical responsibility to consider is that of honest performance reporting. When testing and validating the dispensing accuracy of our machine, it is crucial we do so repeatedly and experimentally to report proper measured errors rather than ideal or theoretical values. By doing this we are letting users know that there is a chance their drinks do not reach a level of commercial certification accuracy, but that if anything it is quite close. Together, all of this aligns with the IEEE principle of truthful representation of system capabilities and limitations, as it makes it clear to users that the result will consistently be within some specific range of values. With the incorporation of the weight sensors and control software too, it also will follow fail-safe principles that are consistent with IEEE and ACM ethical guidelines. Furthermore, we will follow good engineering practices by documenting our design decisions, testing procedures, and any failures to avoid misleading users about the system's reliability.

3.2 Safety

Safety concerns for this project can be generally categorized into electrical ones, mechanical ones, and fluid ones. Starting first with the electrical considerations, the system will operate at low voltages using a 120 ac to 12-volt dc converter as the power supply for an ESP32 microcontroller, sensors, pumps, and motors. All components will be regulated and sized appropriately, proper insulation will exist where needed, and secure connectors will be used. All exposed conductors will also be covered and enclosed to reduce any sort of risk of contact with the liquids, and these two will also be physically separated. Bench testing will use a power supply to verify each subsection's functionality before being connected to the rest of the components, and connectivity will also be tested once components are soldered.

Since the product contains many moving components like pumps and various motors, mechanical safety considerations also come into play. Pinch or entanglement hazards are likely with moving components such as these, however simple fixes do exist to prevent them. To do so, we will enclose all moving parts, limit any/all motor speeds, and ensure that the motors of the stirrer only operate when the weight sensors actively detect that a cup is present. Additionally, the physical geometry of the stirrer will be created such that it avoids any sharp edges without compromising its effectiveness at mixing, and while testing our team will make sure that the power can be quickly disconnected if need be.

With this project relying on liquids being dispensed near electronics, any potential spill or leak risks need to also be managed and minimized. As stated earlier, fluid paths will be physically separated from all electronics wherever possible, and additional insulation will exist wherever it's needed. Ideally, they will be placed such that the sensitive electronics are above the tubes and thus isolated from any potential leaks from damaged tubes. The tubing which will carry the liquids will also be clamped where needed and positioned so that the liquids pour directly into the cup. On the topic of the liquid dispensing system, since this product will handle consumable liquids, all the tubing and containers interacting with it must be from food-safe materials. They also must be cleanable and non-reactive to follow the FDA's food-contact material guidance principles.

More generally now, while working through this project we will also obviously make sure to adhere to the ECE laboratory safety rules. A general project safety check can also be done prior to starting work each time, and it may consist of enclosure checks, leakage checks, and simple wiring checks. All in all, even though this design is theoretically the build of a prototype, the design process is still driven by relevant standards and best practices.

3.3 Societal, Economic, Environmental, and Global Impact

3.3.1 [Societal]

In a societal context, our engineering solution creates an affordable automated drink mixer capable of improving consistency and accessibility in beverage preparation, while ideally helping to reduce measurement errors commonly present with manually pouring. However, this sort of automated alcohol dispensing system could be misused or abused if the right safeguards aren't in place. To reduce this risk, our design makes sure it requires user input per drink, enforces specific measured quantities, and prevents any continuous or uncontrolled dispensing or liquids.

3.3.2 [Economic]

Looking at this solution from an economic perspective, we found that many of the existing products that function like our design are quite expensive and rely on using their branded consumables or pods. Our approach, on the other hand, emphasizes low costs. The machine itself comes with standard containers and no requirements for some proprietary additional components. Instead, once a consumer has the machine, they can select and purchase whichever liquids they want, from whatever provider they want. This effectively supports accessibility and user flexibility, allowing users to choose ingredients which align best with their financial preferences.

3.3.3 [Environmental]

Compared to most existing drink mixing machines, our engineering solution is more environmentally conscious. Most of the existing designs use disposable pods or cartridges, whereas our system is designed to reuse standard containers, effectively reducing packaging waste. These containers for the liquids will, more specifically, be repurposed Gatorade plastic bottles. Thus, if a user would like to dispose of the product at the end of its lifetime, all the materials on it should be safe to recycle.

3.3.4 [Global]

In theory, it can be argued that the underlying technology behind our design could in fact have a larger global impact. Since this is ultimately a low cost and closed loop fluid dispensing system, it could potentially have broader applications in both mixology education and even small-scale automation which goes beyond just beverages. Ultimately, with a transparent and well documented design process then it becomes easy for a user to understand the method by which these drinks are made and allows others to find easier ways to adapt the design for other contexts.

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