Light Sensing Smart Blinds

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Abstract

For our senior project, we will be solving the problem of wasted energy within buildings, because the lights might be turned on inside while ambient light from the sun is also coming through the windows. Rather than having unneeded light, this light controlled curtain will be able to sense the amount of light outside the window and in the room, and then adjust the angle of the blinds and/or dim the light source. This way, the light source will not be running at maximum power output while there is excess light coming through the window. The capabilities of this system will include the ability to measure ambient light inside the room and outside the window, the ability to adjust the angle of each of the blinds on the window, the ability to dim the lights or turn them off, and the ability to change how bright you want the room.

The system will involve a microcontroller, sensors, and a motor to control the angle of the curtains. The microcontroller will be programmed to read sensors, one inside the room and one outside the room, and LED source, and output to a servo motor controlling the curtains. Initially, we will construct the system with a single blind for testing and incorporate an entire array of blinds by the end of the project.

1. General Introduction and Background:

Household window blinds have been in use for many years now, with the first blinds being used by the early Egyptians and Chinese. The Egyptians chose to string reeds together to form blinds, while the Chinese strung together bamboo (Figure 1) in order to keep people safe from the sun. The next big blinds came when the Persians introduced blinds to Venice, which is where the term "Venetian" blinds started. An Englishman named Edward Bevan was award the first patent for Venetian blinds in 1769, using wooden slats. By placing this slats in a frame and manipulating the slats, he discovered you could allow a certain amount of light into a room. John Hampson of New Orleans added the ability to change the angle of the horizontal slats in 1841, which are very similar to the ones still in use today [1].

Figure 1: Bamboo Window Blinds

Hunter Douglas was the first company to develop a light, aluminum Venetian blind in 1946. Other notable improvements include the use of motors to automatically control the blinds rolling up and/or changing the angle. As shown in Figure 2, more popular motorized blinds

include a screen that is being controlled to let in sunlight, although motorized venetian blinds are also available as shown in Figure 3 [6].

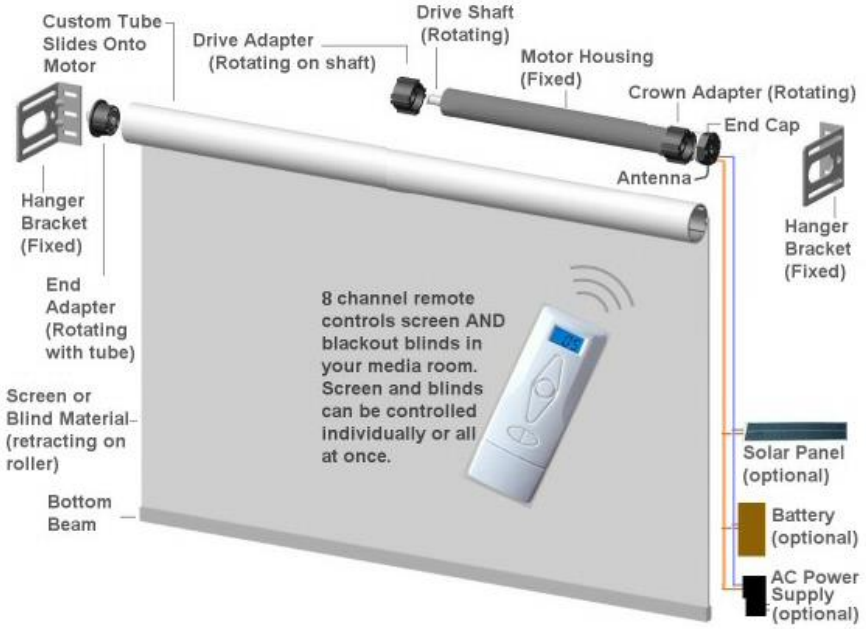

Figure 2: Motorized Blinds Controlling a Screen

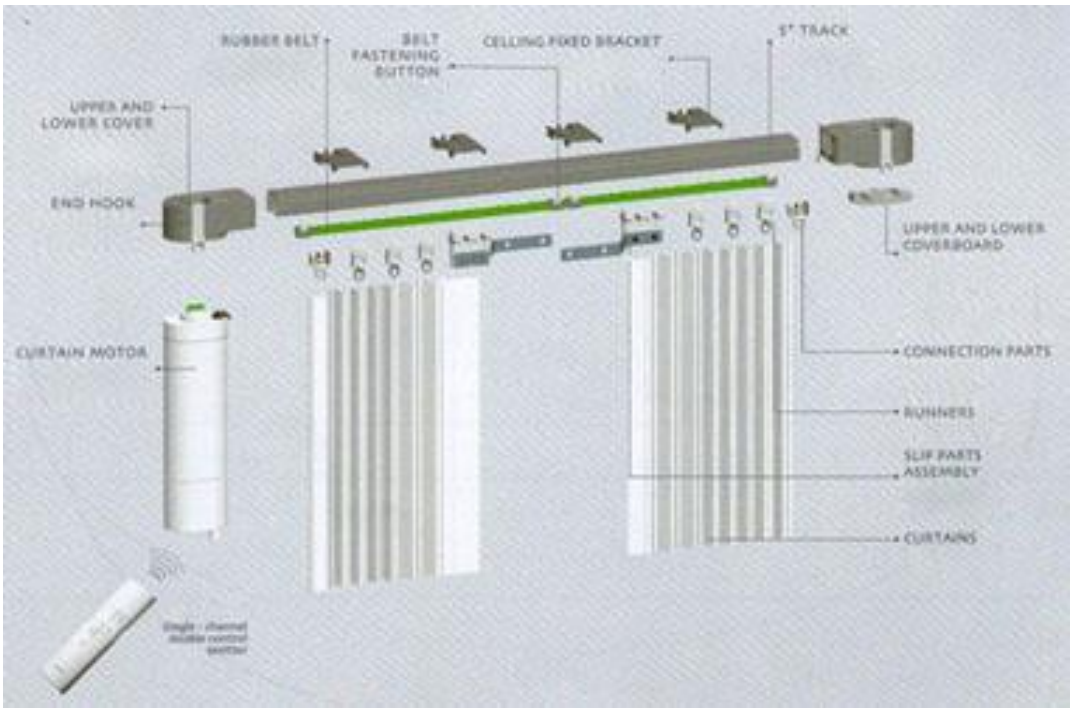

Figure 3: Motorized Venetian Blinds

2. Product Description:

The goal of this project is to create smart blinds: blinds that will cater to the customer's needs by reducing energy consumption and costs. We achieve this by installing our blinds system, which will monitor the amount of light inside a room and outside the window of that room, and will change the angle of the blinds to ensure that an unnecessary amount of light is not being used in the room. For example, if the sun is setting and the customer would like more light in the room, rather than turning on the light completely, only a necessary amount of dimmed light will turn on, while the rest will be used from outside. We target homeowners who are trying to reduce energy costs and save the environment in the process. For many homeowners, we will save years of energy costs with just an up-front charge for our system. Energy bills have been going up in the United States, and customers will be happy to save money. Our solution will help create a green earth, and will be seen in home systems for years to come.

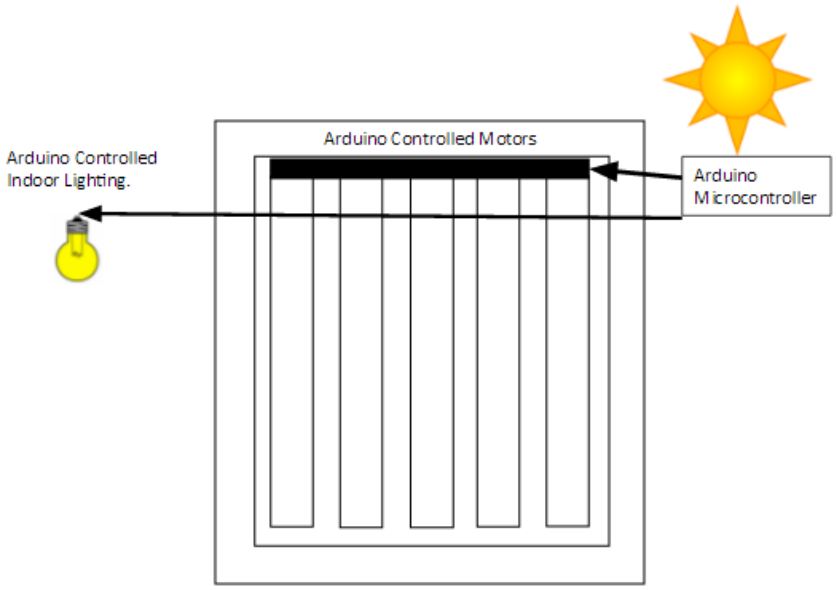

Figure 4: Simple Diagram of Inputs and Outputs of the Smart Blinds

3. Market Research:

There are only a few present solutions that are currently on the market, although no solutions sell the full system of the blinds with the light sensing devices. The first market solution is through a company called RollerTrol™ which sells the sunlight sensor for the blinds system. The first disadvantage of this solution is that the user must manually configure and install the sensor with their motorized blinds, which might be difficult and tedious for the average consumer. The other disadvantage is that the motors and blinds are not include with their design, which makes integration of components potentially more difficult. The next competitor is somfy®, Sunis Indoor Wirefree™ RTS Sun Sensor, which is also selling just the sunlight sensor for the blinds system. The difference between somfy® and RollerTrol™ is that a company called Budget Blinds Corporate is offering to install the somfy® sun sensor with the customer's motorized blinds. This is beneficial because the customer does not need to have a technical background in order for the blinds to be installed. The disadvantage is that this product again assumes the customer already has motorized blinds installed, and now adds the cost of labor for installing the new, sun sensor. Our solution addresses this problem by providing the whole system to the customer, so the: integration of parts is very easy, the customer will not have to pay twice for labor, and we take into account the sunlight outside of the window to make sure the sunlight readings are accurate enough.

4. Customer Archetype

This project's main competitors are only selling the sunlight detector, making their customer archetype's a lot narrower than it could be. By selling and marketing this complete system, there are types of customers: Energy Conscious Homeowners, New Homebuyers, Wealthy Home Owners, Early Adopters, and homeowners in the southwest states. Especially with the rising popularity of smart homes and the growing trend towards Green/LEED buildings, the advantage of selling a system that also incorporates light detection will be a huge hit in the industry [12].

Table 1: Customer Archetype

	Description	Reason	Product Use
Energy Conscious Homeowners	With the energy crisis happening in the world, people of all ages are trying to cut down on their energy usage, with this being an easy, cost-effective way of doing so	They are trying to help save/protect the Earth by reducing their carbon footprint	Reducing energy consumption by better controlling the room temperature and the light needed in the room
New Homebuyers	New homebuyers in the age of 30 – 40 years – old are potential customers, because they are looking to modernize their homes after purchasing them	Smart blinds are new technology that most homeowners will want due to reduced energy costs and convenience of use: automatically adjusting the blinds	By automating the blinds, the customers will not have to manually adjust the blinds, making the home feel more high tech
Wealthy Homeowners	Wealthy homeowners will likely have a lot of nice furniture, which over time, will eventually become damage due to sunlight	Having smart blinds that will automatically close will ensure that the furniture does not get too much sunlight per day, and will therefore not be as damaged	Protecting furniture and prolonging its life
Early Adopters	Early Adopters are people in the age from 20 – 35 are people who enjoy new technologies	Tech savvy people in the age from 20 – 35 will enjoy this system, because of the new technology and having the ability to install a smart system in their homes	Helping to modernize their house/apartments, and add to their collection of new gadgets
Homeowners in the southwest states	Half of the 10 sunniest places in the world are in the American southwest states of Arizona, Nevada and Texas.	Homeowners in these states will utilize this new technology by using more light from outside rather than turning on the lights	Utilizing the environment where sun light is very prevalent each day

Table 2: Industry Competitors

	**3 Day Blinds LLC** manufactures window treatments in the United States. It offers blinds, including wood, faux wood, vertical, mini, vinyl, and cellular blinds; shades, such as cellular, roller, soft roman, horizontal sheer, woven wood, pleated, and solar shades; shutters, including plantation shutters; and curtains/drapes, such as curtains and drapery panels, and decorative hardware. [11]
	**Chicology** offers a full range of both Corded and Cordless window treatments. This includes the standard shades most people are familiar with.Yet ours are different in that we make them simpler, more stylish, and an excellent value combination of quality for the price. [10]
	**Comfortex Window Fashions** is a leading manufacturer and fabricator of custom window treatments headquartered in historic Maplewood, New York which is just outside Albany. Comfortex is proud to offer a complete line of cellular and pleated shades, wood blinds and shutters, sheer horizontal and vertical window shadings and innovative cellular blinds. [9]
	**Decora** creates innovative window covering solutions for the window blind trade. Blinds are brought to life through vibrant colour and design, in addition a selection of unique finishing and style, make us 'Decora'. [8]
	**Draper, Inc.** manufactures and markets window shades and coverings, gymnasium equipment, and projection screens. Its projection screens include projection display systems, video projector mounts and lifts, plasma display mounts and lifts, and presentation easels; and gymnasium equipment include basketball backstops, gym dividers, wall pads, volleyball equipment, batting cages, and wrestling mat hoists. The company offers window shades primarily for commercial, educational, residential, and architectural markets. [7]

The market is projected to reach US $16.7 billion by 2022, because of the array of design ideas, styles, fashion trends and product functionality improvements in this industry [6]. We can assume that a lot of the profit can come from automated blinds due to the growing consumer preference for custom blinds, rising popularity of automated blinds and shades, and rise in smart homes and the ensuing demand for smart-glass based window shade solutions that maximize energy savings. Therefore the market is large enough that our product could breakthrough, because the market is also not dominated by any one competitor [13].

5. Market Description

The light sensing smart blinds system will be accomplished using an Arduino Microcontroller. Using an Arduino development program, the microcontroller will be programmed to read in light from inside and outside the window. These light values will be compared within the code to adjust the blinds to allow a comfortable level of light within the room. The blinds will then be adjusted as to let in a certain level of light. The motors will be servo motors that will adjust their angle to allow the light in. These motors will be controlled by the microcontroller as well and the code for them will also be written within the Arduino program.

The Arduino will be configured to be powered from a wall outlet, allowing the system to be separate of all user interface. Apart from plugging the system in, the user will not need to interact with the system whatsoever. The light bulb itself will also be controllable from the microcontroller to turn off or on depending on the light level in the room. Another benefit of the system is that it requires a very small amount of power, making it very efficient for the user to save money by not wasting any energy powering unnecessary lights.

Current solutions to this problem do exist, however, this product will expand upon and better those solutions. Some products today sense only outdoor or indoor light, making our system superior because it will read both, compare them, and adjust the light in the room. Another solution that currently exists is blinds that are remote-controlled. The benefit this product will have over that solution is that it is entirely self-sufficient and will require no user interface once the system is powered. To conclude this portion, our system will be able to out-perform both existing solutions by taking aspects from both and creating a better solution that will read light in and out of the room, while also requiring no effort from the customer.

What separates our solution from the others is that it will be self-sufficient. This gives our product a huge advantage over competitor's systems. This can be leveraged to customers by expanding on the fact that customers will be able to adjust the light in the room without any interaction from its users, while the system will be able to save the customer money on their power bill.

This type of technology is relatively new and works along with other technologies such as solar panels. The target customers are energy-conscious homeowners that may already be using solar panels and other technology to save themselves money. However, lighting systems like this are not currently being well-addressed in the market today. Our product will enter this corner of the market with a modest initial goal of capturing 10% of the sales among energy-conscious homeowners and give homeowners another option to save money on their energy bill each month.

Entering this market could be a relatively difficult task for us. Our biggest market would most likely be online sales. Creating our own website for our smart blinds would be the next step to generate online sales. Once the site is up and running, another option would be buying google

searches, which is also a low cost of $1-$2 to be placed on their search network. Partnering with these two entities initially would be a huge help. Once these online sales get going, partnering with home appliance chains would be the next step. For example, getting the product placed in a store like Home Depot would be huge asset [1]. This step, however, would not be feasible until the company has established success in other aspects such as online sales. Companies like Home Depot charge around 35-40% for each sale, therefore, this step would only be taken if the company is successful and the market is large enough to make this step.

6. Business Model Canvas Graphic

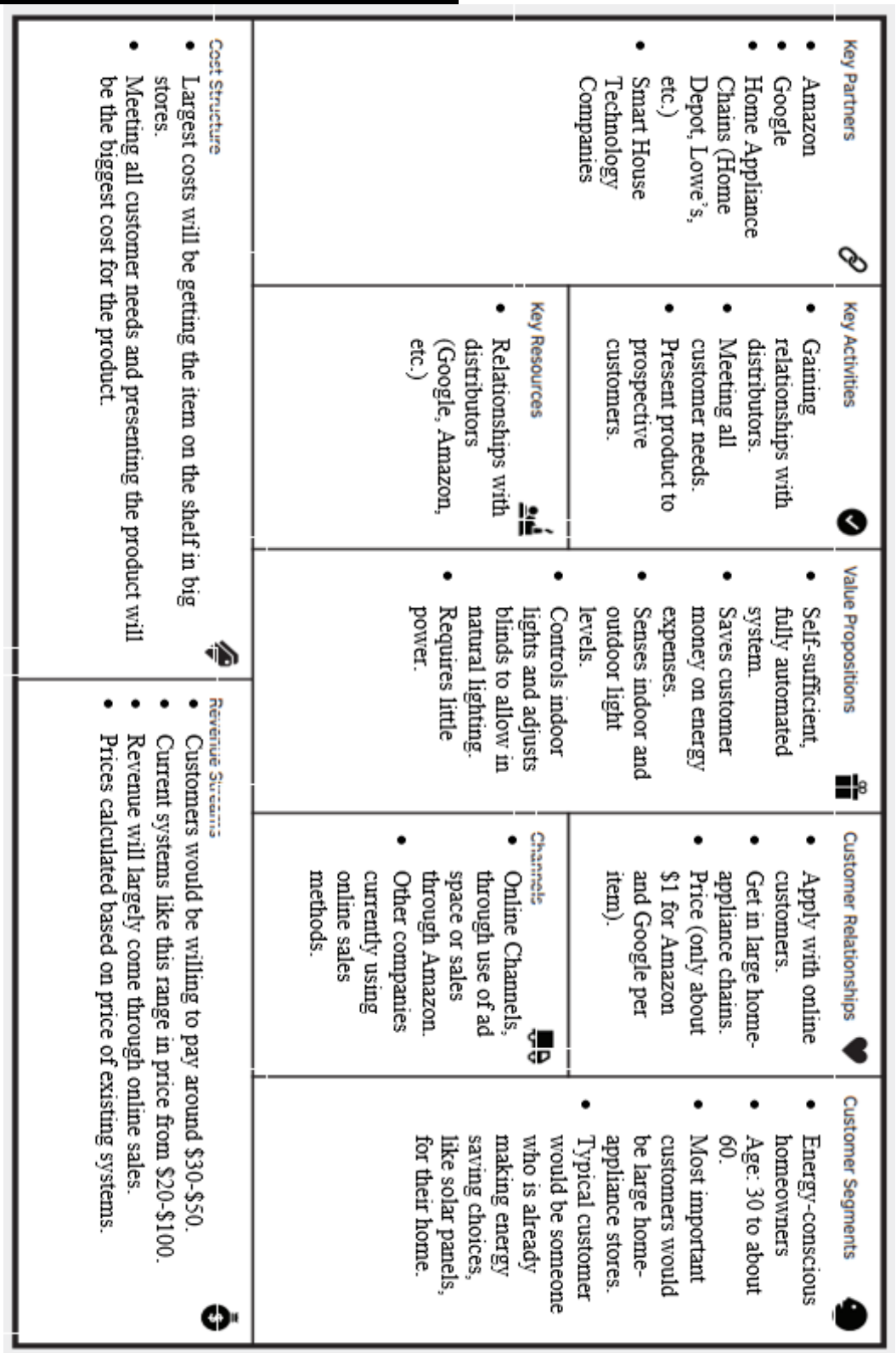

Figure 5: Business Model Canvas Graphic [3]

7. Marketing Requirements

Upon doing research into the more specific area of Smart Blinds, we were able to compile a table of the major market requirements for this product by analyzing the issues that customers have with their current systems. Some of the major issues are cost, automation, user interaction, and ability to integrate other smart technologies. To address the cost, many systems like this go for up to $200. With our system, there is no reason it should be more than about $70 at maximum, and would most likely be around $50. It seems that this is the biggest drawback of the current available systems is that customers are unsure of whether or not these systems are worth $200, or if it is easy enough to manually control their blinds. The issue of automation is the idea of allowing the system to run without the user having to interact with it at all. To accomplish this, our system will always be on, and adjusting lights as needed. As far as integrating the technology with other smart technologies, it seems feasible that the system could easily run with a light dimmer, and rather than turning the indoor lights all the way on or off, they could simply be dimmed instead [4].

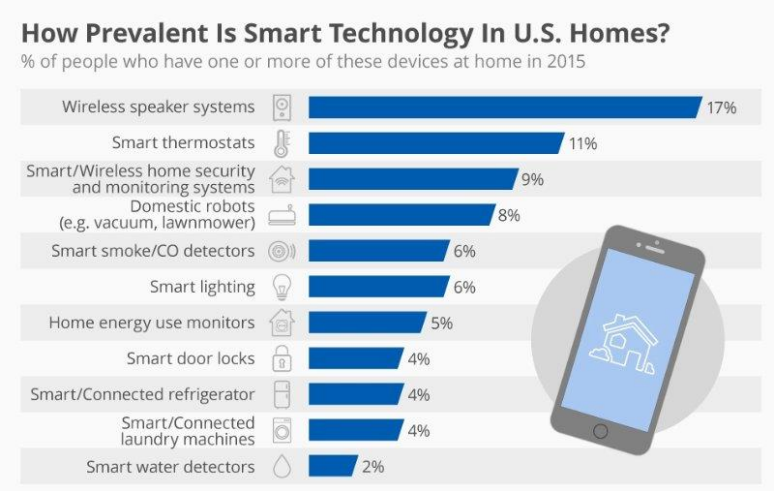

Figure 6: Prevalence of Smart Technology in US Homes [2]

The move towards homeowners making their homes “smart” is something that has really taken off in recent years and shows no signs of slowing down in future years. Our light-sensing smart

blinds fill a very specific niche within this market. As shown in the chart above, this market is already prevalent in homes, with 6% of all homeowners in the US having some kind of smart lighting system, and capturing just 10% of that 6% of homes would be the goal of our company. As more and more people are becoming conscious of their energy bills, systems such as our smart blinds will be in higher demand. For this reason, it is a very exciting time to be entering our product into this market [2]. The chart below displays the growing trend in the smart home market, predicting that it will reach $100 Billion dollars in consumer spending by 2018, and the 6% of these homes using smart lighting makes this a $6 Billion dollar industry we will be attempting to enter.

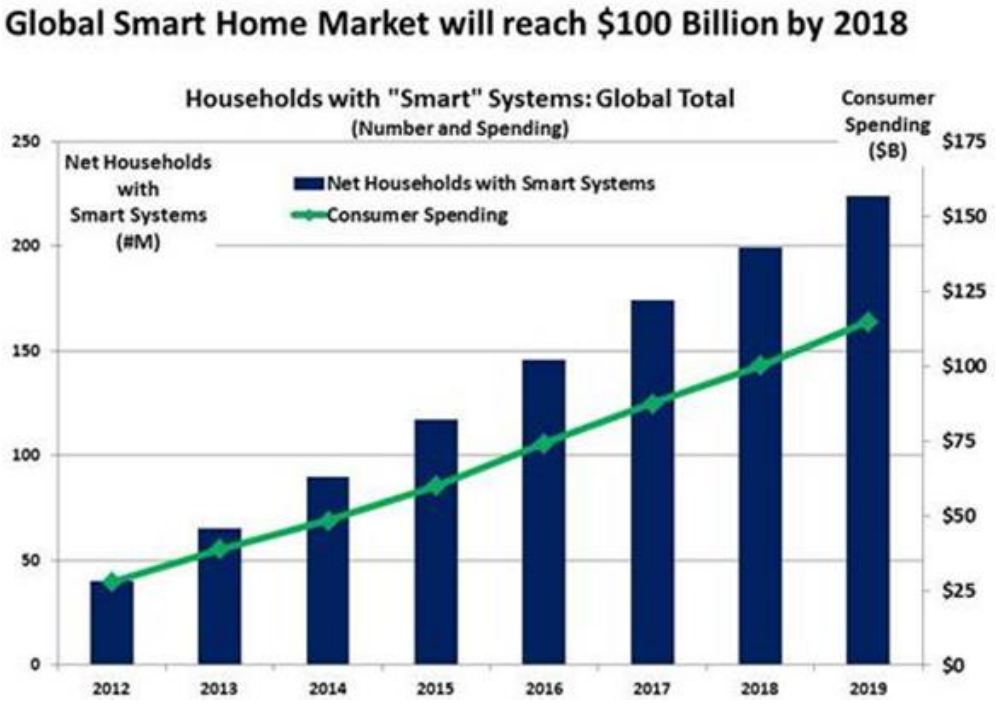

Figure 7: Growth Chart of Global Smart Home Market [2]

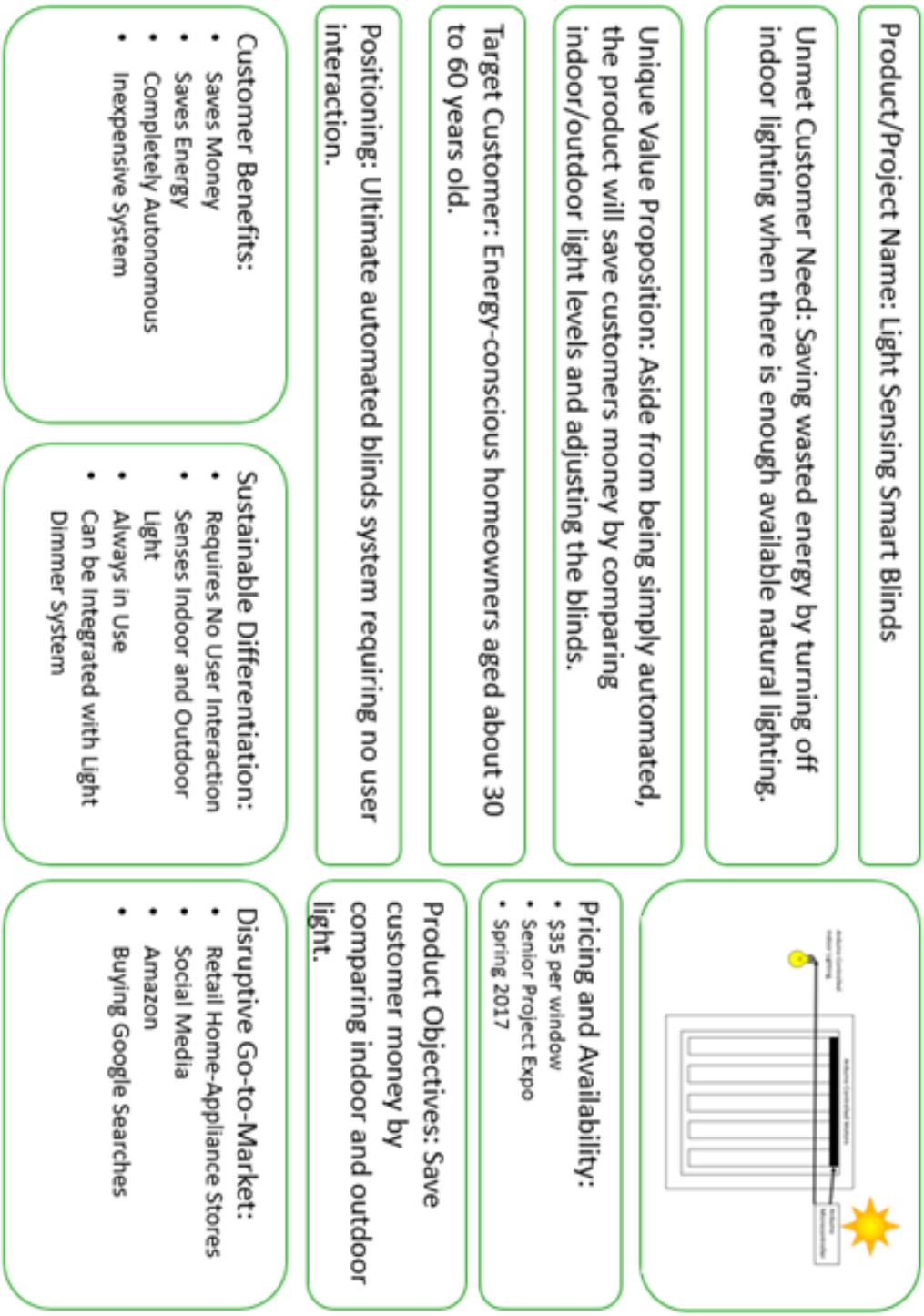

Figure 8: Marketing Data Sheet

Table 3: Marketing Specifications

Requirement Number	Requirement Name	Justification
1	Fully Autonomous	What sets our system apart is the fact that it will be fully autonomous and require no user interaction once it is plugged into a wall outlet, making it even more user-friendly.
2	Senses Indoor/Outdoor Light	The next key feature is that it will read and evaluate both the indoor light levels and outdoor light levels.
3	Controls Blinds with Motor	The blinds will be controlled with stepper motor programmed through the Arduino interface.
4	Turns Indoor Lights ON/OFF	Indoor lights will also be controlled with the Arduino and can be turned on or off depending on outdoor light levels.
5	Compares Indoor and Outdoor Light	Comparing the indoor and outdoor light will allow the system to control the blinds as well as turn off the indoor lights.
6	Cost Effective	The key to this system attracting customers will be its ability to save them money on their monthly power bill, so it's important that the system work autonomously without using too much power and save the homeowner money each month.
7	Allows Comfortable Amount of Light Into Room	Along with saving money, the system must also keep the room comfortable for the customer by allowing in a certain amount of light to be established in the design process.

8. Block Diagram, Requirements, and Specifications

The level 0 block diagram for this light sensing, smart blinds system is shown in Figure 8. There are 4 inputs (the light intensity inside the room, the light intensity outside the room coming through the window, the user desired light intensity inside the room, and power from the wall outlet at 120V RMS) and 2 outputs (the angle of the blinds changing and the brightness of the indoor light bulb changing) for this system.

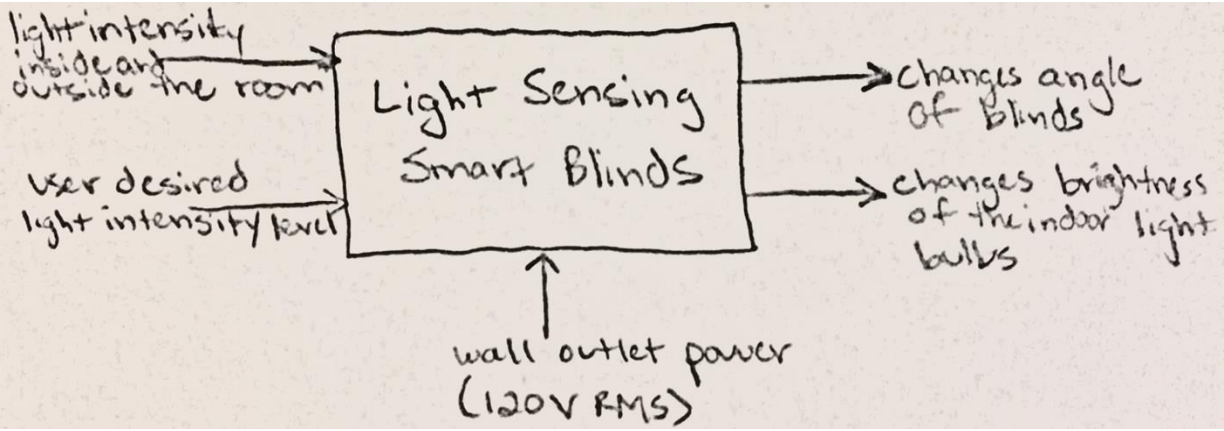

Figure 9: Level 0 Diagram of Light Sensing Smart Blinds

The level 1 block diagram for this light sensing, smart blinds system is shown in Figure 9. Inside the entire system, there are 7 subsystems. Two of the subsystems will be photodiodes, used to measure the intensity of light inside and outside the room. The light dimmer switch is another subsystem which is adjusted by the user to set his/her desired light intensity level inside the room. The wall outlet power goes to the converter subsystem, which will convert the 120V RMS AC to 5V DC for the microcontroller to be powered. This converter subsystem will consist of a full-wave bridge rectifier using schottky diodes, feeding into a buck step down DC-DC converter. The microcontroller subsystem will take 4 inputs (from the photodiodes, the dimmer light switch, and the AC-DC step-down converter) and produce 2 outputs. The microcontroller will first take in the user desired light intensity level, and compare this to the light intensity

outside the room. If the desired light intensity level is lower than the light intensity outside the room, the microcontroller will send a signal to the light dimmer subsystem to turn completely off, and send a signal to the motors' subsystem to decrease the angle of the blinds in order to decrease the amount of light coming in the room. If the desired light intensity level is higher than the light intensity outside the room, the microcontroller will send a signal to the motors to increase the angle of the blinds to allow the maximum amount of light in the room, and will compensate the need for light by adjusting the light dimmer to make the light bulb brighter. A summary of the coding flow diagram is shown in Figure 10.

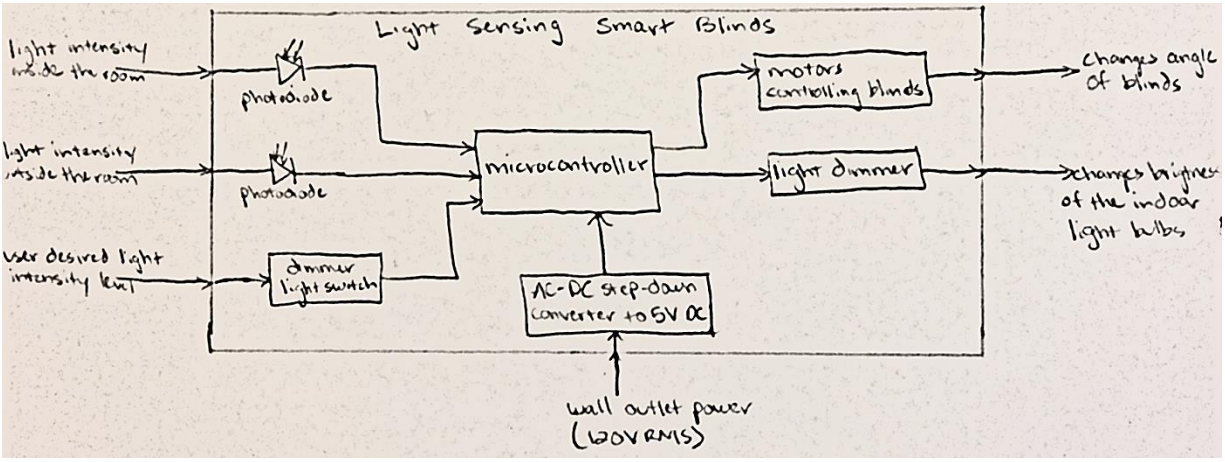

Figure 10: Level 1 Diagram of Light Sensing Smart Blinds

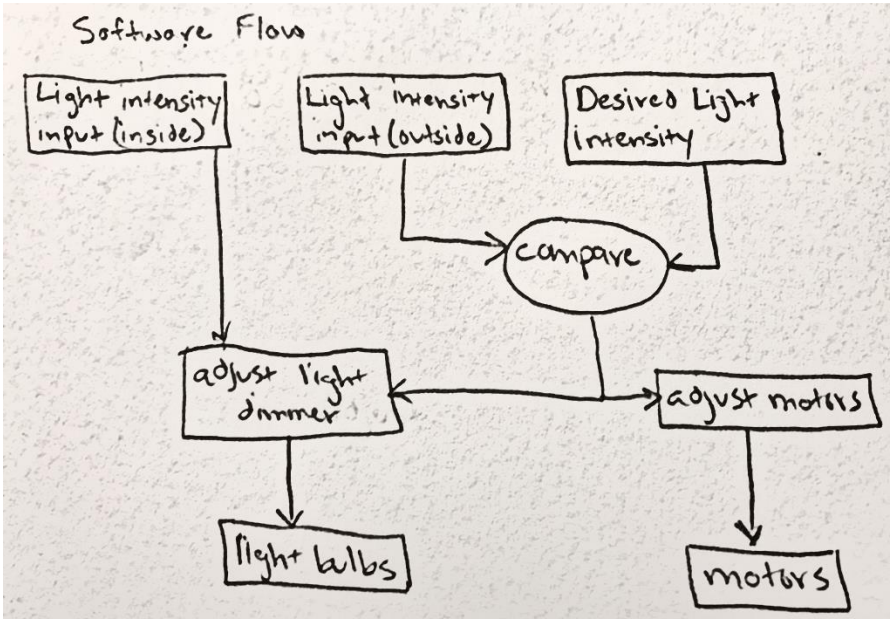

Figure 11: Coding Flow Diagram

Table 4 lists the responsibilities for each team member and the tasks they will have to complete for the entire project to be finished.

Table 4: Responsibilities of Each Team Member

Andrew Hodges	Dimmer light switch subsystem Light Dimmer subsystem Microcontroller subsystem Programming the microcontroller and motor control
Ryan Flick	Photodiode subsystems AC-DC Step Down Converter subsystem Designing the mechanical side of controlling the blinds with the motors, along with motor integration

9. Scheduling

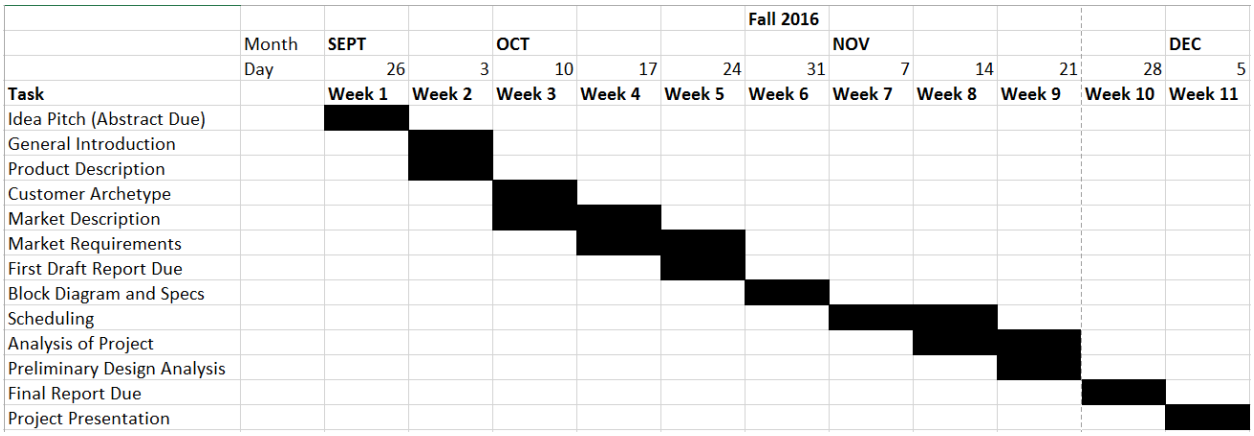

Figure 12: Gantt Chart for Fall Quarter

Figure 13: Gantt Chart for Winter Quarter

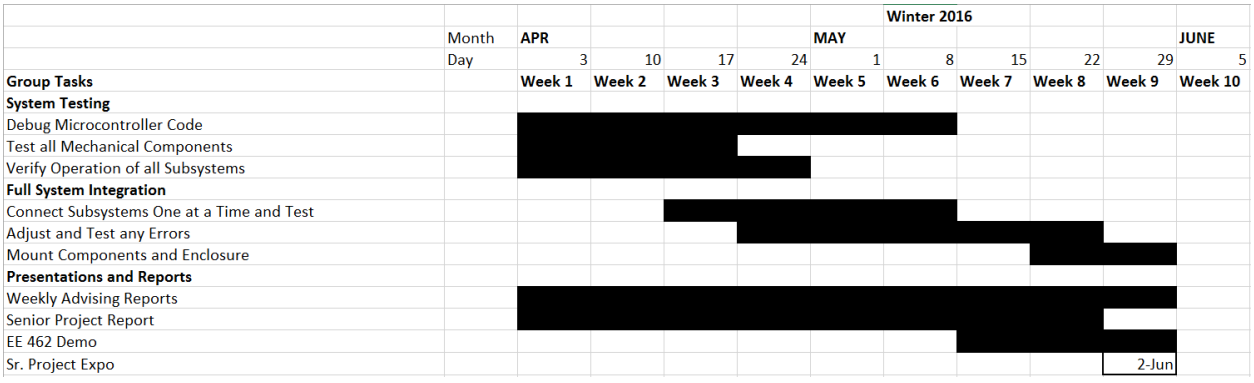

Figure 14: Gantt Chart for Winter Quarter

Items that Could Affect Scheduling

The most extensive part of this project will integrating the code, reading in the signals, and outputting to a light dimmer and servo motor, so getting the code functioning properly could be very time consuming. Also, depending on lead times of components, getting all of the components in our hands could take longer than anticipated.

Cost Estimation

Table 5: Expected Cost (component level)

Item	Number	Cost
Arduino Uno	1	$25
Motor	1 (per blind)	$15
Step-Down Converter	1	$5
Blind	1 (per blind)	$4
Structural Parts	-	$20
Total	-	$69

The table above estimates the cost for our system. If we are to construct a full array of blinds, the cost will go up as an additional motor and blind will be required per blind. This cost should easily be covered by the allotted money for each senior project group.

Resources used to Complete the Project

The internet and past textbooks will be our main sources of any unknown information needed to complete our project. As far as faculty goes, any professors knowledgeable on microcontrollers and power electronics may be consulted, most notably Professor Taufik.

Key Skills Needed to Complete the Project

The most challenging aspect of our project will most likely be the programming of the microcontroller and getting it to interface with the sensors and motor. Looking back on old classwork will be key in completing this portion. Otherwise, as long as we work collaboratively we should have no big issues with any other portions of the project.

10. Preliminary Design Analysis

The major choice in design of our system will most likely be what kind of motor we want to use to control the blinds themselves, and this system will most likely be accomplished using either a stepper or a servo motor, both of which have their advantages. This decision will be made during Winter Quarter, and will come down to which servo motor will allow us to set the blinds to more precise angles. Besides this a simple AC-DC step-down will power the system as a whole. The code will be compiled in Arduino's format. To maximize our efficiency, it will also be important for us to ensure that the system dissipates as little power as possible.

Figure 14 is the preliminary design that we have, similar to Figure 4 from above. Like Figures 2 and 3, we will use existing, motorized blind techniques, while integrating the light sensors, light dimmers, and microcontroller.

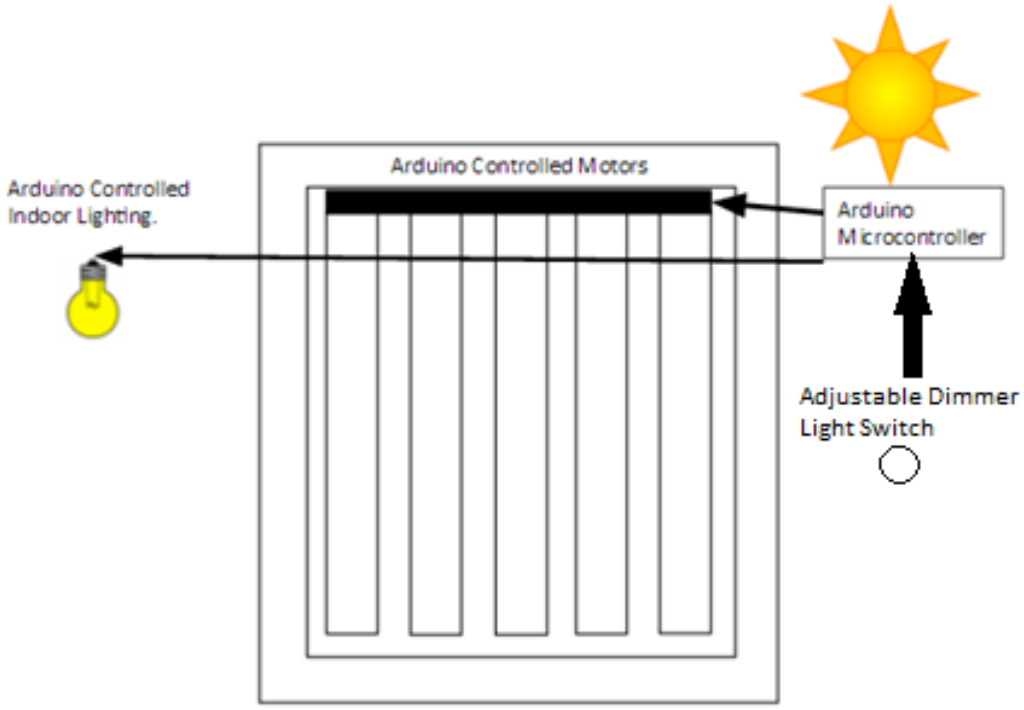

Figure 15: Preliminary Design Option

Appendix A. Analysis of Senior Project

Project Title: Light Sensing Smart Blinds
Students: Andrew Hodges, Ryan Flick
Advisor: Taufik

1. Summary of Functional Requirements
    a. This project will be able to sense the amount of light outside the window and in the room, and then adjust the angle of the blinds and/or dim the light source. This way, the light source will not be running at maximum power output while there is excess light coming through the window. It will be controlled using a microcontroller, which will read the data from the photodiodes and the dimmer light switch to calculate at what angle the blinds should be at, and what intensity the light source should be at.
2. Primary Constraints
    a. There are a couple of constraints that will be tough as we assemble this project. The first is to make sure the servo motors can generate enough torque to move all the blinds smoothly without getting jammed. The next constraint is to figure out a cheap, but acceptable microcontroller that will have the processing power needed for our design. Trying to minimize the cost will be very vital as we market the product. Finally, a big constraint is being able to effectively measure the ambient light inside and outside the room. The project relies on the photodiodes accurately reading the light levels to decide when there is enough light outside, that the light source does not need to emit any light.
3. Economic
    a. What will impact the result?
        i. Human Capital: The development of this device creates jobs in engineering, manufacturing, sales, and marketing.
        ii. Financial Capital: This device will sell and create profit for investors and will create a new niche within the automated blinds market.
        iii. Natural Capital: The project will use both mechanical and electronic components, using a microcontroller, photodiodes, light dimmer, light source, servo motors, and physical blinds. These parts are difficult to dispose of because of the different materials required to make them.
        iv. Costs: The commercial sale price is subject to change, as the projected component prices may vary after further research is conducted. An estimated production cost of $100 for a small array of blinds, leading to retail price of $150-$200. The product would hit the market around a year after the senior project expo, leaving time for any final changes and cost-cutting in the manufacturing time.

Table 6: Cost Evaluation

Purchase	**Cost**	**Explanation**
Microcontroller Motors Converter Blind Structural Parts Sensors	\$25-\$50 \$15-\$150 \$5-\$20 \$4-\$20 \$20 \$2	Estimated Component Parts
Website	\$1,000-\$2,500	Estimated Cost of Hiring a designer, maintenance, and buying a domain name
Testing	\$1,000	Professional testing of product
Labor	500 Hrs (\$10/Hr)	Optimistic Labor Cost
Total	\$7,071-\$8,762	

These estimations make up the entire cost of developing our product and launching it, including having it tested. At just the senior project level, our cost will not exceed \$200.
Using the equation from Ford and Coulson Chapter 10, the optimal cost would be (cost1) = 450hrs x \$10 = \$4,500. The least optimal cost would be (cost2) = 550hrs x \$14 = \$7,700. The most likely cost would be (cost3) = 500hrs x \$12 = \$6,000. The result labor estimation is:

$$Cost = \frac{cost1 + 4cost3 + cost2}{6} = \$6{,}033$$

4. If manufactured on a commercial basis:
    a. Estimated number of devices sold per year: ~1000 units
    b. Estimated manufacturing cost for each device: \$69 (See above)
    c. Estimated purchase price for each unit: \$100
    d. Estimated profit per year: \$31,000
    e. Estimated Cost for User to operate device: \$0.01/Hr (Electricity Cost)
5. Environmental
    a. The environmental impacts occur due to the fabrication of all the parts used for this project, especially the microcontroller, servo motors and photodiodes. Correct recycling of these parts is necessary, or else harmful chemicals may harm the environment affecting people and animals that live near it.
6. Manufacturability
    a. Manufacturing of this project will be very complex due to the number of components required to construct this system. With motors, microcontrollers, and a physical blinds system, manufacturing will be very tough.
7. Sustainability
    a. Describe any issues or challenges associated with maintaining the completed device.
        i. One issue with maintaining the device, is ensuring that the components are well protected and will not be damaged easily, specifically the

photodiodes. Another challenge is to ensure that the blinds will not become jammed, which might cause the motors to break.

b. Describe how the product impacts the sustainable use of resources.
    i. When manufacturing this product, the recycling of parts must be monitored to ensure the product does not have a huge environmental footprint.
c. Describe any upgrades that would improve the design of the project.
    i. An improvement of the mechanical system of the blinds would greatly benefit this project. Ensuring that the blinds do not jam and that the rest of the parts are well protected are very important for this project, to make sure the product lasts a long time.
d. Describe any issues or challenges associated with upgrading the design.
    i. Currently we are not very well involved in mechanical systems and efficient ways to build them, which is why upgrading this design would be difficult. Especially in terms of correct materials to use when building this design, additional input from mechanical engineering students would be very beneficial.

8. Ethical
    a. One ethical implication of this product is the benefit of reducing energy consumption by utilizing light through windows. A negative implication is that due to the amount of parts being used, manufacturing this system will not be very environmentally friendly, unless all parts are recycled correctly.
9. Health and Safety
    a. One safety concern with this project is that a few of the components will be exposed and could be protruding enough to poke somebody if they walk too close to the system. Along these lines, if something is wrong with the motors, there is no way to manually adjust the blinds because this is a purely automated system. Children getting caught in the blinds could be a concern because of this.
10. Social and Political
    a. Social issues with this design include that some customers will benefit more than others for this project. In places with little sunlight, the system will not be used to its full potential, and will instead just use the light source inside. Political issues include that correct advertising must be present, or legal issues will occur as well as bad ethics reflected on our company.
    b. This project affects the whole automated blinds industry, including companies like Chicology and Draper. They will lose more market share, and may try to create a competitive system like this one. Advertising using platforms like Amazon, social media, and Google searches will also be affected since we must add that into our cost.

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