Final Project Report

Light Flicker - Group A2

Written By:

Ian Desson [300005479]
Matthew Edwards [300033277]
Karan Musty [300021224]

Date: December 10, 2018

GNG2101[A]

Faculty of Engineering

University of Ottawa

Abstract

During the semester, we were tasked to work with a client to develop a solution to a problem they are having. The focus of this project was accessibility. For our project, we had to develop a light flicker that was more easily accessible for our client as they had limited motor abilities. We had to produce different designs based off what our client needed. From there we were to develop the designs into prototypes that would be tested and demonstrated to our client. After we demonstrated our prototypes, we would use our client's feedback to improve upon our product to ensure that we are meeting their needs. Additionally, we had to put together a business model, and perform an economic analysis.

Table of Contents

List of Tables

List of Figures

1-Introduction

Light switches are difficult to use for those with limited motor abilities. Their small size and raised height makes them difficult to reach for with a limited motor range. Thus, to use their light switches, people with limited motor abilities require help from others. An example of this, would be our client who is unable to use the light switch in her room. Our client is a patient of St. Vincent's Hospital who desires the independence to control their own lights. Our solution attempts to solve this without interfering with the hospital's electrical system, without being invasive of the hospital's environment and can be controlled anywhere in the room.

2-Process

2.1-Need Identification

Before visiting our client, we were given a brief description of the problem we would need to solve. However, not much information was given and we had more questions about the project than information was given. We prepared a list of uncertainties and questions that we wanted to ask. Such as, what part of using the flicker is the most difficult and how often does the switch need to be used?

From these questions and other discussion, we came up with a list of our client's need statements (See Table 1). We combined these need statements into a Problem Statement that would define the problem we needed to solve. Our problem state summarizes our client's situation and that their desired solution is a bionic system that can control the lights without interfering with the hospital's electrical system.

Table 1: Customer Statements vs. Corresponding Need Statement

Customer Statement	**Need Statement**
"The electrical in the hospital is not like in a normal house, it operates under a very specific building code. If there was a fire the patients would have a hard time leaving the building "	The light flicker can be installed regardless of the existing electrical systems.
"I have difficulty extending my arms and can't press very hard on things without getting tired"	The light flicker remote operates without needing to press physical buttons.
"I would like for the lights to come on when it starts getting dark"	The light flicker is able to automatically operate depending on time of day.

With this problem statement, we benchmarked for other potential solutions that are already on the market. We found two devices that attempt to solve our problem. The first one, the SwitchMate, attempts to solve the problem using a large touch sensor with voice controls that is placed over the light switch. However, many reviews online suggest that it has a poor battery life and will stop working even when the batteries are charged.

Additionally, we found the KASA Smart Wi-Fi Light Switch. This light switch is operable over wifi, via an Amazon Alexa, Google Home or Smart Device. However, this required replacing the pre-existing conventional light switch which was not allowed as it would be considered interfering with the hospital's electrical system.

We also came up with a list target specifications that we had to work towards (See Table 2). For example, since our client is in a hospital, we would need to avoid tripping hazards and interfering with the hospital's electrical system in any fashion. We also remain under our $100 budget and avoid being invasive of the hospital's environment so as to avoid any other hazards.

Table 2: Target Specifications

Metrics	**Description**	**Matching Need**
Performance	Must fully function at least 2 times a day.	Working around dusk automatically.
Service Life	Should last around a year before requiring repair.	Ease of use.
Input	Touch, voice or very easy-to-press button.	Without use of physical buttons/ switches.
Installation	Must not interfere with the Hospital's electrical system. (Must be put on top of the flicker)	Being installed without interfering with the electrical system.
Cost	Must cost less than 100$.	Budget limit of 100$.
Materials	Should use light and cheap materials.	Budget limit of 100$.
Documentation/Training	Should be fairly simple; only requiring single input for on and off.	Ease of use.
Environment	Can not interfere with the environment especially the electrical system.	Being installed without interfering with the electrical system.
Quality/Reliability	Should last at least a year and be easily repairable.	Ease of use.
Weight	Should not weigh too much so that it is easy to handle and doesn't fall off of the wall.	Not being invasive of the hospital environment.
Size	Must not be bigger than the original flicker.	Not being invasive of the hospital environment.
Safety	Must not be a fire hazard.	It was mentioned that a previous solution was a potential fire hazard due to its wiring.

2.2-Ideation

Following this we began to brainstorm different concepts and ideas that could be used in solutions to our problem. Immediately, we found it necessary to divide the problem into two problems. The first problem was controlling the light switch while the second was receiving input.

First off, to control the light switch itself, we had the idea of using the pre-existing screws on the light switch baseboard as means to mount our controlling solution onto the light switch. Some of the ideas for moving the light switch include moving the switch with two motors, one above and one below. Also, there was the idea of using a fork handle to move the switch up and down. Another idea was to use a servo motor that move the switch. Also, there was the idea of using a sleeve that would cover the light switch and would move with the light switch. Lastly, there was the idea of using a stepper motor with a wheel attached that would control the light switch. All of these ideas required a microcontroller to control the various motors and power them when necessary.

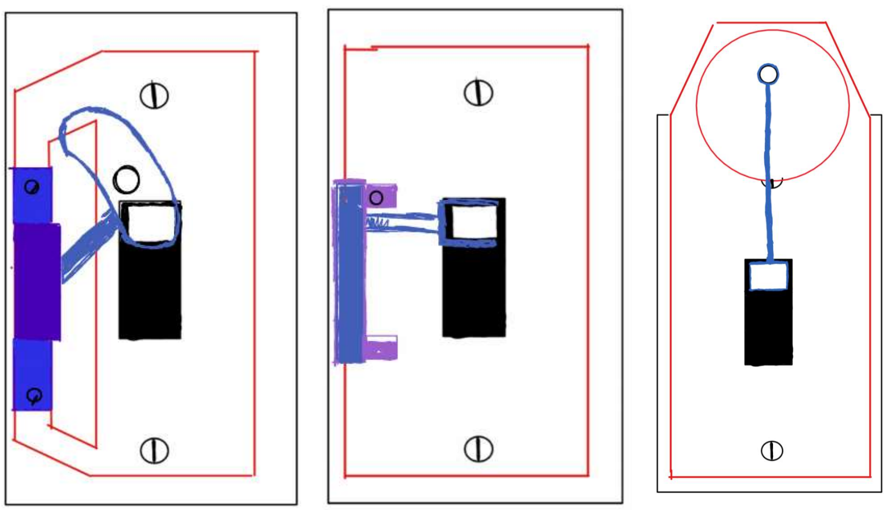

Figure 1: (From Left to Right) Servo Motor Design Drawing, Fork Handle Design Drawing, Stepper Motor with wheel design drawing.

Secondly, there were many ideas as to how to receive input. For example, there was the idea of a large touch sensor, using motion sensors to detect when the user was in a certain spot of the room, movement sensors to detect a deliberate movement, a desktop application, an android application and using foot pedals. These ideas required a Bluetooth or wifi connection to the device that would control the lights.

With all of these ideas, we went through how they satisfy each of our target specifications. For example, we decided to not use both the sleeve and two motors because although they would allow hospital staff to also use the lights, they require two motors which is not as cost effective as the solutions that only use one. Additionally, we decided to not use the movement sensors as we did not have enough time with the client in the year to train for false positives. For example, we only had three client meetings and we did not know what movements would be the most comfortable for our client.

Ultimately, we wanted to use a large touch sensor that would connect to a microcontroller via bluetooth and flick the switch. In the end, we decided to use an android application as we did not have the budget for a touch pad, and we went with controlling the light switch with the wheel based off of client feedback.

2.3-Project Plan

Now that we had a solution to work with, we had to produce a project plan that we would follow for the rest of the semester to develop our solution. We established a Gantt Chart describing the flow of our project, its milestones, its dependencies and its progress. We did this by dividing our project into five major sections. The first section was the initiation and planning phase where we had to figure out what the problem is, come up with solutions and decide on one and decide what materials were needed to develop it. Next, we had the two prototype development phases where we would develop our models, show them to our client and with their feedback, develop them into physical prototypes. Then, with the prototypes, we would test them and analyze their functionalities. Next, using the data from the previous prototypes, we would assemble a final product and demonstrate it as part of the deployment section. All of these sections were dependent on the section that came before it. Although, the Business Analysis section was not dependent on the other sections as it was mostly theoretical.

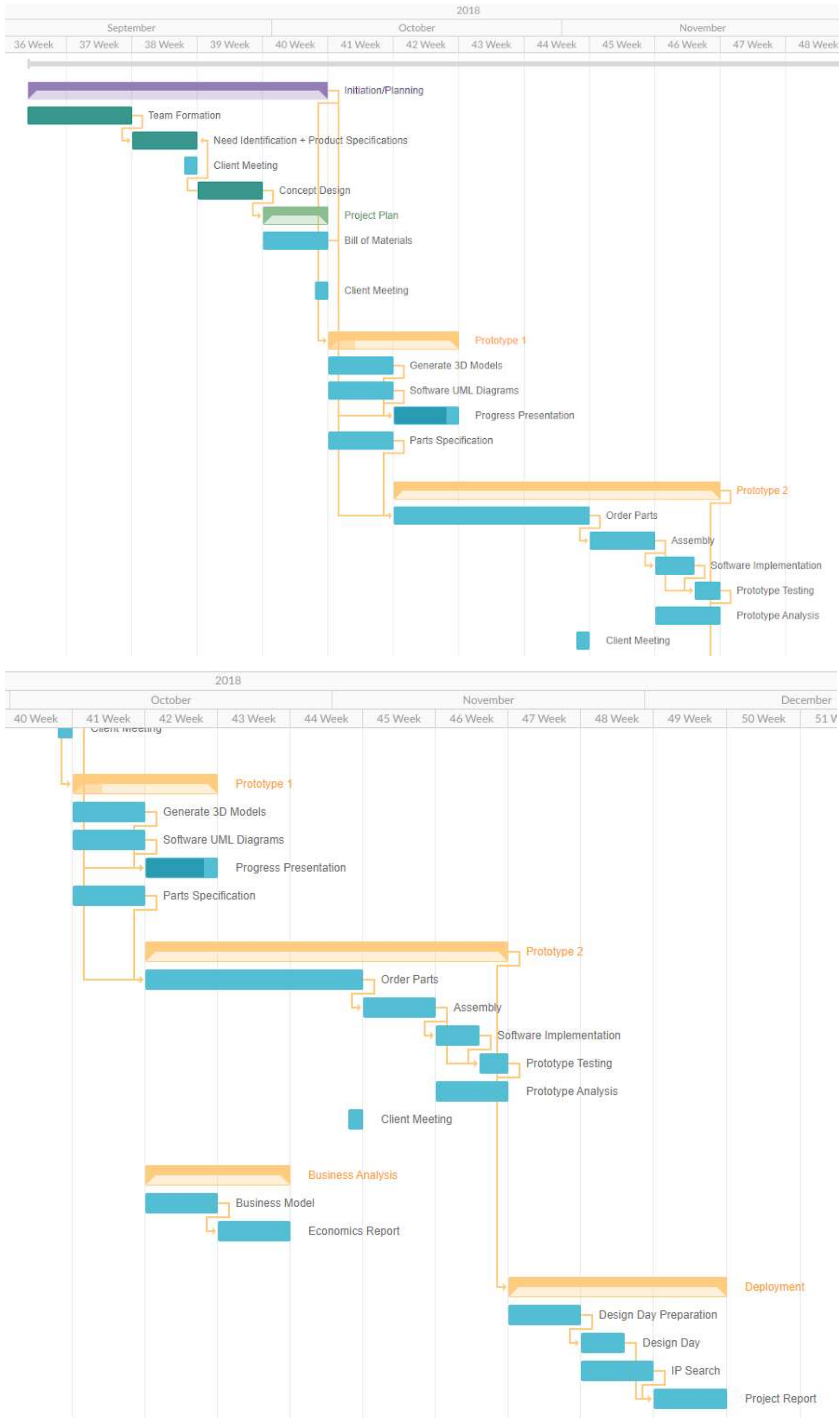

Figure 2: Gantt Chart of Project Plan

Additionally, we had to create a Bill of Materials that would contain all of the necessary components of our project and justify their costs. In total, our bill of materials was expected to cost about $70.59 which was about 30% less than our $100 budget (See Table 3).

Table 3: Bill of materials

Product and Amount Needed	Cost	Link
1 x Raspberry Zero W	$14.00	**https://www.adafruit.com/product/3708**
1 x Stepper Motor	$4.95	**https://www.adafruit.com/product/858**
1 x Stepper Motor Driver Board	$7.66	**https://www.amazon.ca/dp/B071D8X3V7/ref=cm_sw_r_other_apa_7oQUBbFSCN6X3**
1 x Battery Bank	$36.99	**https://www.amazon.ca/Power-Bank-Portable-Charger-24000mAh/dp/B07F2B4TYZ/ref=sr_1_13?s=electronics&ie=UTF8&qid=1538953393&sr=1-13&keywords=battery+bank**
1 x Aluminum Rod (5" long x .28" Dia)	**Free (Sourced by Karan)**	**N/a**
1 x (6" x 6") 12 gauge Aluminum sheet metal square	**Free (Sourced by Karan)**	**N/a**
1 x Micro SD Card	**$6.99**	**https://www.amazon.ca/Kingston-microSDHC-Memory-SDC4-8GB/dp/B001CQT0X4/ref=sr_1_6?ie=UTF8&qid=1538957622&sr=8-6&keywords=raspberry+pi+sd+card**

Lastly, we had to perform a feasibility study. The feasibility study was designed to discover if our team was capable of meeting the requirements for this project. This meant the technical, economic, legal, operational and scheduling requirements.

In our case, we met most of the technical requirements as our team comprised of two mechanical engineering students and a software engineering student. This meant that the only technical expertise that we were missing was that of an electrical engineering student. To compensate for this, we decided that we would perform any research and self-teaching necessary.

As well, we met the economic requirements as our expenditure on components was less than the budget. Also, this expenditure was justified since these components were required to complete our solution.

To meet the legal requirements of this project, we had to avoid using anything that would violate hospital safety guidelines and patient privacy guidelines.

We met the operational guidelines as we had a project plan to follow and whether or not we would meet the requirements was left to the individuals who would complete their respective tasks on-time.

Lastly, we met the scheduling guidelines as they followed a chronological order. As long as individuals could accomplish their tasks on time, the next person would be able to start their task on-time. Additionally, to compensate for any loss, some tasks were given extra time during planning so that there would still be enough time even if they failed to complete the task during the ideal time period.

Using this information, we determined that it was feasible for our team to complete the project as we met technical, economic, legal, operational and scheduling requirements.

2.4-Prototypes

For our first prototype, we developed a low fidelity model of what we envisioned the final product would look like. We were testing for overall sizing and for the type of 3D printed orientation that would work best to produce the structural support needed for a sturdy wall mount.

Figure 3: Print of First Prototype

Next, taking what we learned from our first prototype and feedback from client meet two, we developed what would be our second prototype. This medium fidelity model solidified the final wall mount design and provided us with an opportunity to test and assemble the electronic portion our our product.

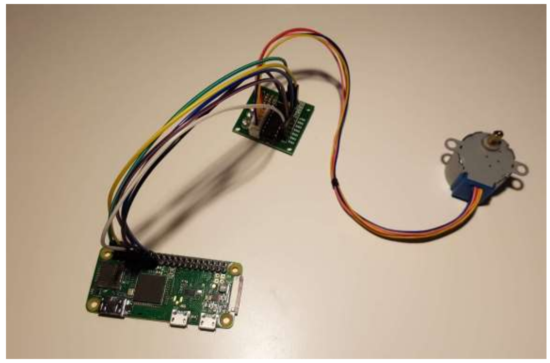

Figure 4: Electrical Components of 2nd Prototype

Finally utilizing what we had learned from both prototypes 1 and 2 we produced our high fidelity comprehensive prototype that consisted of minor changes to the wall mount as well as assembly of the wheel and rod mechanism that would physically move the switch into the desired position. This prototype represents our final solution.

Figure 5: Assembled Final Product

2.6-Business Model

The next step in our process was the business analysis part of our project. First we had to develop a business model that we could follow if we were a real company. We came up with two different business models. The first one was to sell our product as an accessible light switch to hospitals. As well, we had the idea of selling our product as a smart home device that would allow consumers to control the lights in their home anywhere over the internet.

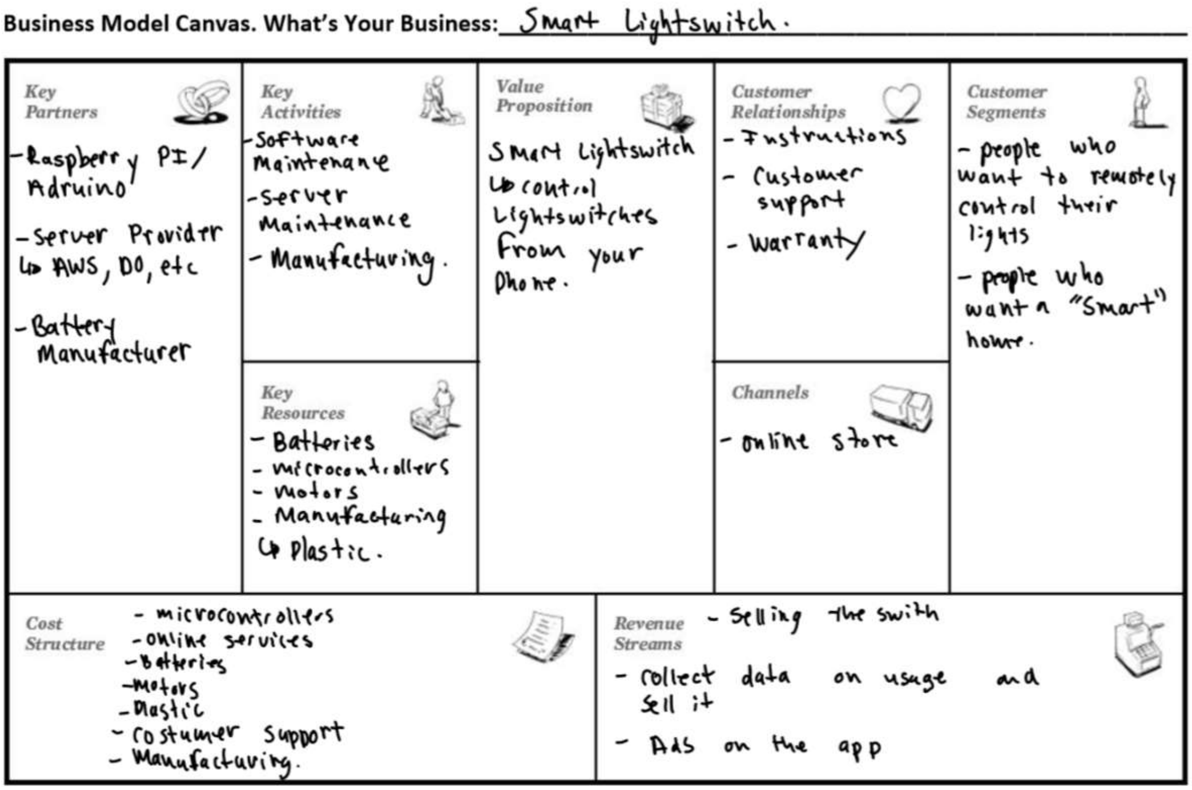

Figure 6: Business Model Canvas

First off, an accessible light switch is already our product. However, we investigated to see what the different aspects of this business model would be. In doing this, we discovered that most of the business model's aspects are the same as the other business model where we sell our product as a smart home device. For example, the key resources would be the same since we use the same materials and components.

As well, we would still need Raspberry Pi and Battery manufacturers as partners. The key differences lie in the customer segments and channels. For example, for an accessible light switch, the customer segments would be hospitals and those who need accessible light switches. Whereas, a smart home device customer segments are people who want to remotely control their lights and those who want a smart home devices so as to have a 'smart' home. Additionally, with the smart home device, we not only have the revenue stream of selling the switch but also we can collect data from our users and there is the possibility of ad revenue from our app.

After this, we needed to validate our business assumptions. Our assumptions were that there will be consumers with enough interest to buy our product, that we have the technical expertise to develop this product, and we assumed that we will make a profit. Our riskiest assumption was that there will be enough interest in our product.

To validate our riskiest assumption, we planned to attempt to sell our idea to an investor. We chose this since it is the most cost effective way to validate our product. By attempting to sell it to an investor, we have a possibility of gaining adventure capital and they have more knowledge of the market so they could give us feedback on our product which would allow us to further improve on it.

2.7-Economic Analysis

The second part of our business analysis was creating an economics report. In this report, we had to determine what our variable, fixed, direct and indirect costs were (Table 4). Then we determined our cost per unit (Table 5). Using this cost per unit, we developed a 3-year income statement that demonstrated our gross profit, operating expenses and operating income.

Table 4: Costs

Costs			
Variable	Fixed	Direct	Indirect
• Raw materials • Packaging • Labour costs • Shipping costs	• Building rental • Machinery and tools costs • Utility payments • Salaries • Insurance	• Direct Materials (BOM) • Labour Costs • Commissioned work	• Utilities • Quality control costs • Production supervision salaries • Accounting and legal expenses

Table 5: Cost Per Unit

Product & Required Quantity	**Cost**
Raspberry Zero W: 1	$14.00
Stepper Motor: 1	$4.95
Driver Board for Stepper Motor: 1	$7.66
Battery Bank: 1	$36.99
Aluminum Rod (Length = 5” & Diameter = 0.28”): 1	Donated by Spectra Aluminum (Value = $17.00)
Micro SD Card: 1	$6.99
PLA Filament	$2.00
Total:	**$89.59**

		Year 1			
	Income ($)			Expenses ($)	
Price per unit :	180		Cost per unit:	89.59	
Units Sold:	500		Units produced:	750	
Sales Income:	90000		Packaging:	0.5	
			Production Cost:	67567.5	
Gross Profit:	22432.5				
			Monthly Operating		
			Monthly Rent:	5000	
			Administrative:	2240	
			Utilities:	300	
			Marketing:	500	
			Salaries:	6400	
			Machinery:	500	
			Operating Costs:	173280	
Operating Income:	-150847.5				

Year 2

Income ($)		Expenses ($)	
Price per unit:	180	Cost per unit:	89.59
Units Sold:	1000	Units Produced:	750
Sales Income:	180000	Packaging:	0.5
		Production Cost:	67567.5
Gross Profit:	112432.5		
		Monthly Operating	
		Monthly Rent:	5000
		Administrative:	2240
		Utilities:	300
		Marketing:	500
		Salaries:	6400
		Operating Costs:	173280
Operating Income:	-60847.5		

Year 3

Income ($)		Expenses ($)	
Price Per Unit:	180	Cost per unit:	89.59
Units Sold	1500	Units Produced:	1500
Sales Income:	270000	Packaging:	0.5
		Production Cost:	135135
Gross Profit:	134865		
		Monthly Operating	
		Monthly Rent:	5000
		Administrative:	2240
		Utilities:	300
		Marketing:	500
		Salaries:	6400
		Operating Costs:	173280
Operating Income:	-38415		

Figure 7: 3-year Income Statement

With this data, we determined that we would not earn a profit from our first three years of operation due to the high cost of our product. After this, we performed a net-present value analysis and break-even analysis to determine how we could earn a profit (Figure 6).

Net Present Value Analysis:

Present value of a future cash flow = Future cash flow / (1 + Discount rate) (Squared by the number of periods of discounting)

Present value of a future cash flow = 22432.5 / (1 + 0.10)^1

Present value of a future cash flow = $20393.18

Break-even point:

Fixed Costs / (Price - Variable Costs) = Break-even point in units
173280 / (180-89.59) = 1916.60
=1920 Light flickers to break even

Figure 8: Net Present Value and Break Even Analysis

It was determined that in order to earn a profit, we needed to sell about 1920 light flickers.

3-User Manual

To install our product, you must screw the mount on top of the light switch using the two screws already on the light switch base. To power the device, all that is necessary is to plug the USB into the battery pack. The device will power on (this can take up to 90 seconds). During this time, secure the bucket on the actual light flicker. The device should begin controlling the lights every 5 seconds as it is in demo mode. There currently is no way to stop demo mode without ssh-ing onto the raspberry pi and using the command:

```
sudo systemctl motor.service stop
```

To modify the contents of the Raspberry Pi Zero W, you will need to remove the battery from the mount. You will find the Raspberry Pi in the below where the battery was. Currently, there are only two ways to connect to the Pi. The least intensive method

is to connect the raspberry pi to a computer and using puTTy, ssh into it. This is a headless setup meaning that there is no graphical interface available.
(Here is a tutorial for the setup: https://desertbot.io/blog/ssh-into-pi-zero-over-usb)
(Note that this also requires to have Bonjour installed on Windows)

The other possible way is to remove the SD card and rewrite its contents using another device. It is suggested to put Raspbian onto the SD Card using a tool like Rufus. From there you will have to power the Raspberry Pi by plugging a power source (a computer is the safest option) into the PWR micro-usb port. Then place the SD card (with the operating system loaded on it) into the Raspberry Pi's SD Card slot. The operating system will install (this can take up to 5 minutes). From here, there are a few options of connecting to the raspberry pi. There is the tutorial listed above as well as some other options:
(It should be noted that the tutorial above was the only option we found successful)

- https://github.com/initialstate/pi-zero-w-motion-sensor/wiki/Part-1.-Setting-Up-the-Pi-Zero-W
- https://core-electronics.com.au/tutorials/raspberry-pi-zerow-headless-wifi-setup.html

4-Conclusion

In conclusion, we went through the design process and failed to deliver on a final product. Some of the process included creating need statements, using these statements to develop a problem statement, and developing some design concepts. With these concepts, we decided on a successful product and created prototypes for it. However, when we finally received all of our components, we were unable to get key components like bluetooth to work. Ultimately, we were unable to develop our product any further because we could not afford any other components due to our budget.

Some things that we learned are what it's like to work with a client and try to develop a product that solves their problems. This meant a constant questioning of if we were actually solving our client's problem at each step of the project.

Also, we learned to bring our technical skills together. Our team consisted of two mechanical engineers and one software engineer. This meant that we all had very different technical skills. So, we learned to combine our strengths and dedicate them to their respective areas of development. For example, our software engineer was dedicated towards developing our android app while the mechanical engineers had to develop the device that would mechanically control the light switch.

Lastly, we learned to compromise as a team. We had to compromise on many things throughout the development of our product. For example, in the beginning, we had many solutions and different ideas of how to solve our client's problem. We also all had different ideas as to what would work and what would not. We had to compromise on an idea so that we could move forward with the development of our product. Another compromise was made during our budgeting/ bill of materials. We were unable to afford a full Raspberry Pi 3 due to the price of our battery so we had compromised on using the Raspberry Pi Zero W as it had most of the same features but was smaller and less powerful.

If we were to do this again, we would probably start by using a better Raspberry Pi as the one that we used had very poor bluetooth connectivity. Additionally, a lot of time was spent just trying to setup the raspberry pi because the regular setup did not work. Additionally, we would probably spend less money on the battery and order our parts even earlier so that we can spend more time testing our product.

5-Bibliography

SimplySmartHome. (n.d.). SwitchMate Light Switch. Retrieved December 10, 2018, from https://www.mysimplysmarthome.com/products/switchmate-switch-normal/

TP-Link. (n.d.). HS200 | Kasa Smart Wi-Fi Light Switch. Retrieved December 10, 2018, from https://www.tp-link.com/us/products/details/cat-5622_HS200.html