PROJECT J: FINAL REPORT

Work presented to Mr. Muslim Majeed
In the class of GNG 1103B – Engineering Design
By Group B1 - Shed 1 - Automation 1

University of Ottawa
April 16, 2018

Table of Contents

Introduction

Many indigenous people are struggling to find adequate housing on their reserves. Our client, Monique, from Barriere Lake, whom we had met with to gather information to assist in resolving the lack of housing that this specific indigenous community was suffering from. The community is situated on a Native reserve approximately 3 hours north of Ottawa. The client provided us with a comprehensive explanation of the current condition of the reserve, and essential information which were later interpreted as constraints, functional and non-functional requirements, the target specifications and was indispensable in determining the actual problem after further analysis of the data gathered from the meeting.

The client required an inexpensive, self-sufficient and transportable housing unit. Later it was decided that we were constructing a modular shed to satiate the client’s needs. Our team was specifically responsible for all the electrical components and circuitry present within the shed (with the exception of the solar panels).

User need identification

From the project background given to us it was obvious that we needed our device to be both automatic and safe so that a patient would be able to have improved blood flow and reduced stress on their body by tilting themselves back whenever they need to. As we were working with many elderly clients the device would have to be simple enough to use, as well as able to help users of multiple differing physical capabilities.

The client explained to us that she is living on an impoverished algonquin reserve of approximately 400 residents north of Ottawa. The reserve is 59 acres sitting at the edge of Barriere Lake on a flat, sandy terrain. Most homes are 1-2 bedroom units with 10-12 occupants. The electrical grid consists of generators at maximum capacity - unable to support more housing.

There exists no stores/groceries on the reserve, nor are there any repair services (plumbers, carpenters, etc.). Due to the lack of employment on the reserve (85% unemployed), most families generate extremely little or no income - relying instead on farmed/hunted foods and their own construction/crafting skills.

Outside of the main community, the residents build small homes on their hunting grounds. These have no electricity or running water. Stoves used are commonly wood-fired or propane-burning. Using these stoves inside presents a fire hazard, but is often seen as the only option when outside temperatures can drop below -25℃.

Overall, the community is largely cut off from modern services, and any new housing must be sustained using renewable energy and affordable materials. The client advised that she needs a small modular housing unit that can exist sustainably off the grid, provide shelter and warmth in low-temperature conditions, and last many years with minimal repair. The shed must be able to be transported to the reserve and constructed with ease.

Automation Needs Identification

From the interview, here are the list of automation needs we identified:

- Inexpensive materials in case of replacement/repairs
- Safe
- The electronic equipment must be energy-efficient
- A bypass/manual system to control appliances within the shed
- Usable all year round
- Small design
- Effective low-cost lighting
- Solar powered; self-sufficient energy wise
- Design must be less than 1000$ total(100$ for the automation team)
- Durable to last several years
- Reliable and low-maintenance

We have translated the main needs of our customer into prioritized list of solution requirements:

Prioritized Needs for Automated Systems

Need Priority	Need Description

1	Entirely solar powered; self-sufficient energy wise
2	Safe electrical design
3	Energy efficient, energy-saving
4	Durable/reliable (operates in various environmental conditions)
5	Manual bypass for automated devices
6	Inexpensive materials/parts (Total cost less than 100$)
7	Small & space efficient design

Problem Statement:

"The client requires a self-sufficient, transportable shed. The shed must be inexpensive, energy efficient, safe, and sustainable for year round usage in rough weather conditions. It must generate enough electricity to power simple appliances and devices, and require no high-skilled maintenance."

As our project is about improving the living of families in isolated communities, we were focused on creating an automated design that would safely provide all of the basic home utilities a home requires, and ensured that these utilities would run on Solar powered energy alone.

Research and Possible Design Solutions

We generated differing Design Solutions for the following subsystems:

- Lighting
- Sensors
- Computer/Circuit/interface

- Breakers

<u>Lighting:</u>

Concept Idea 1 : Glolux 75 Watt Equivalent LED Light Bulb - Indoor

This light bulb provides 1100 lumens in lighting which is more than enough for the dimensions of the shed. Since the basic premise of the shed design is efficiency, this light bulb uses Light Emitting Diodes, which inherently are the best energy saving options. As per our benchmarking, this lightbulb is the most effective option. Unlike most LEDs on the market this brand has the ability to be dimmed which will further our energy savings. The quality of the Glolux is reflected in its cost - nearly 20$ per bulb.

The lightbulb will be installed in the centre of the room. It will either be turned on/off or dimmed through :

a) a switch on the wall,
b) sensors

c) through a display interface connected to the computer.

Advantages	**Disadvantages**
● Strong lighting power ● Energy efficient	● Expensive

- Dimmable - Durable (25000 hrs)	

Concept Idea 2 : Philips LED Non-Dimmable A19 Frosted Light Bulb (Asaad/Adam)

This lightbulb is a cheaper alternative to the Glolux light bulbs, costing only about $3 per bulb! Choosing this bulb will save roughly $13 on each bulb, making it extremely advantageous to our budget as it will save roughly $50 in total. It provides less light as the Glolux (300 lumens dimmer, at 800 lm), but will still function as an adequate source. The wattage is also lower, at only 8 Watts as compared to 11 Watts, which will save more energy. The downside to using this bulb will be the shorter lifespan, at only 11 000 hours as opposed to 25 000 hours. However, considering that these bulbs come in a pack of 16 rather than 6 like the Glolux, these may last longer overall when looking from a lifespan-cost ratio.

Advantages	**Disadvantages**
- Cheap - Low Wattage	- Relatively Short Lifespan (11000h) - Non-Dimmable

Concept Idea 3 : TCP 60W Equivalent CFL Mini spring A Lamp Spiral Light Bulb-Indoor

This option only costs \$2.05/ lightbulb making it a very affordable option. The bulb is smaller than the other options due to its spiral shape. However the bulb requires a significantly higher amount of wattage compared to the other two (14W as opposed to 11 or 8) yet only has a brightness of 800 lumens. The lifespan of this bulb is also very short.

Advantages	**Disadvantages**
● Cheap ● Small	● Relatively Short Lifespan (10 000h) ● Not very bright ● Higher Wattage (14W)

Sensors:

Concept Idea 1 : Sensky BS033C 110V Motion/Occupancy Sensor Light Switch

Motion sensors, while they do add to the complexity of the electrical system in general, certainly do have a fair amount of benefits. Firstly and most importantly, it will save energy by turning the lights off when they are not required. While sensors can get expensive, they are still within the specified budget. Most sensors also contain a bypass system(a switch) which allows you to turn the lights on or off in case the sensor malfunctions. This specific sensor has an adjustable time delay of 10 seconds to 30 minutes, a 180 Degree view with reliable performance, up to 29 foot coverage, and a motion detection speed of 0.6~1.5m/s

Where the sensor installed will generally depend on two factors:
1. The general shape of the shed
2. Where the sensor will get the greatest effective angle

The sensor will likely be installed in
a) A convenient position which has a good view of the door to turn on the lights on when somebody enters
b) A corner, since the shed is likely to be rectangular.

This sensor will likely be used for the entire shed and not for the faucet(a different one for the faucet)

Advantages	***Disadvantages***
- Can save a decent amount of energy - Contains a manual bypass system in case the sensor malfunctions - This specific sensor only costs $12.99	- Difficult to repair if you’re not skilled - Requires programming and adequate installation

Possible Location of Sensor and Light Fixture Within Shed

Concept Idea 2: Adjustable PIR Motion Sensor

Whereas this sensor may not have as many functions or capabilities as higher end sensors, a Passive Infrared (PIR) sensor certainly has every capability necessary to function as a motion detector light switch. In fact lights are the most common use for PIR sensors. PIR sensors can be purchased for as little as $3.37 on websites such as robotshop.com.

Advantages	***Disadvantages***
● Can save a decent amount of energy ● Extremely Cheap at $3.37 online ● Easy to understand due to simple design and limited functions	● Lacks the functionality and versatility of most other sensors.

Concept Idea 3: iTouchless EZ Faucet - Touch-Free Automatic Sensor Faucet Adapter (Godwin and Ben)

This faucet is available at retailers such as The Home DepotTM for prices around $47. Hands free faucets are surprisingly expensive, most of them reaching the $400 mark. As this specific faucet is one tenth of the price it is a very affordable option to choose. This faucet does however work on battery power which would add expenses to the owner. The faucet just screws onto a pre-existing faucet making it incredibly simple to install.

Advantages	***Disadvantages***
● Can save a lot of water ● Easy to install or replace ● Relatively cheap compared to other models on the market	● Still Expensive at around $47 ● Requires batteries which is a recurring cost to the client

Computer/Circuit/Interface

Concept Idea 1 : Programmable Touchscreen Interface with Raspberry Pi Computer

Raspberry Pi would serve as the main computer for the entire automation system within the shed. The programming capabilities will allow us to manipulate every variable, device, and subsystem routed through the computer. Installed behind an enclosed compartment near the entrance of the shed, the raspberry Pi would be protected from accidental physical damage but also easily accessible in case of damage or malfunction. All electric wires would be routed through this compartment as well.

In addition, we would instal a programmable touch screen device to the Raspberry Pi to easily access, modify, and troubleshoot devices, sensors, lights, etc. Not only will this be easy for our client to use, but also easy for the engineers to change settings that might only be possible when connected to a personal computer. The touchscreen can be installed on top or near the compartment that contains the Raspberry Pi, thereby accessible to the client upon entry.

Advantages	**Disadvantages**
● Easy to use ● Changes setting/operations ● Second manual bypass ● Aesthetically pleasing	● Difficult to repair ● Costly ● Time consuming to program

Concept Idea 2: Tablet/Smartphone Apps that control the house's lighting, temperature etc:

The most up to date technology that allows users to customize and program their own preferences in home automation is through apps. These apps can be downloaded on their personal devices (tablets, phones, laptops) and their settings/preferences can be customized on the app. This would allow easier user interface and improved usability. From one app the entire home can be controlled, from inside or outside the home. All of the electronic devices (lights, temperature, and security system) can be controlled through a network that the app would be connected to, as well as these devices. The apps would allow these devices to be scheduled according to the user and their needs. They would be connected to the wifi network in the home which would allow the app to connect and control these devices from anywhere (provided there is accessible wifi).

The advantages of this are that it is very easy to use and accessible from anywhere in the world, gives the user more personalized control over the home and it's automated devices. Developing and creating the app wouldn't be too expensive which would allow more people to download and use it, however getting matching components that can be connected to the app would be hard to find and rather expensive. This type of user control would require the user to have access to a personal device and internet, which would be disadvantageous in situations where wifi is not easily accessible.

Advantages	**Disadvantages**
● Incredibly versatile ● Easy to use ● Apps will be continually updated by third party companies(e.g PHILIPS)	● The matching components (i.e Philips Hue lights,smart lighting, etc…) are expensive ● This option would require the user to possess a smartphone and internet access

Concept Idea 3: Light Switch that controls lights and outlets (which includes temperature):

Our other idea's so far have been decently higher tech, but really at the end of the day if it comes down to money or time we could put in a simple light switch to turn on and off the power to outlets and lights. The advantage of this is that everyone knows how a light switch works and it's decently easy to find and control in the dark as well if you're coming in from outside.

What also gives an advantage to a lightswitch is that if there are any problems with lighting, etc. any electrician could come by and fix it rather than a very specialized individual to look at our raspberry pi touchscreen in concept 1 or going through patches in the app store to fix any bugs with our app for concept 2.

Advantages:	Disadvantages:
- Easy to use - Cheap - Accessible to anyone	- Not as much control

Breakers

Concept Idea 1: Fuse Circuit Breaker, 12V DC Circuit Breaker Trolling Motor Auto Car Marine Boat Bike Stereo Audio Inline Fuse Inverter Audio Reset (100A) (Godwin and Ben)

This option ranges from $20 to $23, putting it at a reasonable price, although slightly more expensive than the following concept. This specific breaker is very space efficient as it is very small. This breaker features a manual reset. The largest set back is that the range of possible breaking amperages is on the lower end ranging from 50 - 150 meaning that using a lot of electricity may be difficult. The one main advantage of this breaker is the fact that the voltage can range from 12-24V giving us more options.

Advantages:	Disadvantages:
- Cheap - Small - Manual Reset - Different voltage options (12-24V)	- Breaking Amperage possibilities are small (50, 60, 80, 100 or 150) A

Concept Idea 2: 150Amp Circuit Breaker with Manual Reset,Inline Fuse Inverter for Car Marine Boat Bike Stereo Audio:

This would be our cheapest option going from 17.99 CAD with an 80A breaking Amperage to 22.99 CAD with a 300A breaking amperage. It is a fairly average size of 8 x 5.2 x 4 (cm) making it easy to tuck away in a corner and also is host to a manual reset if things go awry.

Advantages:	Disadvantages:
- Cheapest option - Small - Wide variety of larger different amperages if necessary (80, 100, 150, 200, 300) - Manual Reset	- This product isn’t precisely meant to be used as a breaker for lights therefore we might come into some difficulties

Concept Idea 3: High Current 150 Amp 0 or 4 Gauge AWG Circuit Breaker 12 Volt Car Audio Fuse:

This is the most expensive choice of the three concepts at $28.34. This option also only comes with one possible breaking amperage (150A) this is the highest possible option for the first concept, and the middle possible option for the second concept. This choice is also the largest of the three and like the other two it comes with a manual reset feature.

Advantages:	Disadvantages:
- Manual Reset - Small (yet biggest of three options)	- Expensive - Not as flexible with breaking amperage (150A)

Design Criteria, Benchmarking, Target Specifications

After assessing and prioritizing the needs of the client, we defined the design criteria to be of two categories, the mandatory needs that must be met in our design and some optional design criteria that the client would like to have. Most importantly, the client requires a self sufficient functional house with automated amenities that would make living easier. From our client interview, we can summarize the clients list of needs in the following order of importance:

1. Entirely solar powered; self-sufficient energy wise
2. Safe electrical design
3. Energy efficient, energy saver
4. Durable/reliable (operates in various environmental conditions)
5. Water tap motion sensor
6. Automatic (sensor activated) Indoor Light
7. Automatic (sensor activated) Outdoor Light

8. Easily repairable (Little to no access to repair services)
9. Manual bypass for automated devices
10. Inexpensive materials/parts (total cost less than 100$)
11. Small and space efficient design
12. Mini fridge/small appliance usage

From these needs, we have narrowed down our mandatory and optional design criteria

Mandatory:

- Solar powered
- Safe electrical design
- Energy efficient
- Able to withstand various environmental conditions
- Indoor, outdoor lights and tap with sensors
- Manuel bypass for the tap

Optional Features:

- Small and space efficient design
- Manual bypass for the lights
- Easy access to electronics for repairs
- Inexpensive parts (total cost less than 100$)
- Aesthetically pleasing
- Mini Fridge
- Touchscreen interface
- Ability to small devices through outlets

Prioritized Needs for Automated Systems

Need Priority	Need Description
1	Entirely solar powered; self-sufficient energy wise
2	Safe electrical design
3	Energy efficient, energy-saving

4	Durable/reliable (operates in various environmental conditions)
5	Manual bypass for automated devices
6	Inexpensive materials/parts (Total cost less than 100$)
7	Small & space efficient design

Benchmarking

Motion Detectors:

	Maestro Motion Sensor switch, 2-Amp, Single-Pole, White	***Heath/Zenith HZ-5316-BZ Deluxe Motion Sensor with DualBrite***	***Sensky Motion Sensor Switch, Occupancy Sensor Switch***
Price (CAD)	29.85	31.14	17.99
Detection Angle	180	240	180
Range (ft)	30	100	29
Voltage (V)	120	120	110
Wattage (W)	250	500	0.45
Dimensions (in.)	2.4 x 4 x 5.8	3.1 x 3.3 x4.4	6.3 x1.97x 3.15
Time-out period	1, 5, 15, 30 mins	1, 5, 10, 20 mins	10s to 30min
Bypass switch?	No	Yes	Yes
Other features	-"XCT sensing technology", which detects fine motion (such as turning the pages of a book) ensuring lights do not turn off	-Selectable light timer, adjustable detection sensitivity,provides energy saving 2 level lighting operating at half power until motion is detected and full power	-Automatically turns off lights when no heat signature is detected in room -Will not turn on in light conditions (daylight)

	inadvertently even when you are sitting/standing in place. -Ambient Light detection so lights will not turn on if there is sufficient daylight in the room	lighting when motion is detected.	

Light bulbs:

	Philips LED Non-Dimmable A19 Frosted Light Bulb	***Glolux 75 Watt Equivalent LED Light Bulb***	***AmazonBasics 75 Watt Equivalent, A19 LED Light Bulb***	***TCP 60W Equivalent CFL Mini Spring A Lamp Spiral Light Bulb***	***Aero-Tech ULA-33***	***PAR38 LED Flood Light Bulb***
Price (CAD)	44.50 (16 Pack)	92.70 (6 Pack)	18.35	20.46 (10 Pack)	25.29	14.95(USD)
Voltage(Volts)	120	120	120	120	120	110
Wattage(Watts)	8	11	11.5	14	150	20
Luminous Flux(lm)	800	1100	1000	800	1350	1800
Dimensions(Inches)	4.2 x 2.4 x 2.4	2.76 X 2.76 X 5.12	5 x 5 x 3 inches	4.4 x 1.8 x 1.8 inches	5 x 4.8 x 6.6 inches	4.7 x 4.7 x 5.3 inches
Shape	A19	A19	A19	Spiral	ULA-33	PAR38
Bulb Type	LED	LED	LED	CFL	Krypton	LED
Lifespan (hours)	10 950	25 000	15 000	10 000	20 000	50 000
Usage	Indoors	Indoors	Indoors	Indoors	Outdoors	Outdoors

Fuses/Breakers:

	Fuse Circuit Breaker, 12V DC Circuit Breaker Trolling Motor Auto Car Marine Boat Bike Stereo Audio Inline Fuse Inverter Audio Reset (100A	***150Amp Circuit Breaker with Manual Reset,Inline Fuse Inverter for Car Marine Boat Bike Stereo Audio***	***High Current 150 Amp 0 or 4 Gauge AWG Circuit Breaker 12 Volt Car Audio Fuse***
Price (CAD)	19.99 - 22.99	18.99	28.34
Breaking Amperage (A)	50, 60, 80, 100, or 150	80, 100, 150, 200, 300	150
Voltage (V)	12 - 24	12	12
Dimensions (cm)	9.8 X 4.1	8 x 5.2 x 4	8.5 x 7 x 5
Manual Reset?	Yes	Yes	Yes

Target Specifications

From the prioritized list above, target specifications and metrics have been set to appropriately measure the level to which the needs is met.

Need #	**Metric**	**Units**	**Marginal Value**	**Target Value**	**Level of Importance (1: least important - 5: very important)**
3	Efficiency	Watt Loss (%)	>40%	>50%	5

8 & 10	Repairability	Difficulty	Medium	Easy	3
1 & 3	Solar Energy Usage	Watts (W)	<150/hr	<100/hr	5
12	External device usability	YES/NO	NO	YES	1
6 & 7	Sensor Outdoor/Indoor light	Sensitivity (meters)	> 2 outdoor >.5 indoor	> 3 outdoor > .8 indoor	3
11	Size/Space Use	Small/Medium/Large	Medium	Small	2
3, 6 & 7	Lighting	List Type	LED/fluorescent	LED	4
9	Touchscreen I/O Interface	YES/NO	NO	YES	1
9	Switch Bypass (lights/tap)	YES/NO	YES	YES	4
2	Safety Rating	Low/Medium/High	Medium/High	High	5
5	Water Tap Motion Sensor	Sensitivity (centimeters)	< 15	< 10	3
10	Cost	Dollars ($)	<150	<100	2
1	Power Source	List Type	Solar	Solar	5

Prototyping

Prototype 1

In order to build a final functioning prototype, key components of a design need to be tested as to avoid problems further on in the design process. A detailed outline of the prototyping test plan has been included to focus the groups activities throughout the next few weeks till final prototype. For the shed automation, a low-cost, medium fidelity prototype will be analyzed and tested with different purposes. The prototype is created as per client/user feedback, specifically in the way in user interacts with the automation devices. Also, the prototype is useful for internal purposes aimed at testing the electrical circuit design and device placement.

Prototype I

Figure 1 & 2: Visual representation prototype of circuit design and placement in out the sustainable shed

The nature of the automation system makes it illogical to build a first prototype in a physical state. Once more is know about the general design layout, a physical prototype with high fidelity can be designed. Above is an accurate visual design of the automation system that will guide our future prototype plans.

As mentioned in our project plan, the objectives of prototype I is to create an accurate low-cost model that will test two concepts:

1. Client’s feedback with respect to placement of the interface and devices.
2. The general circuit layout.

The automation subsystem is fairly comprehensive in design and functionality. There are several essential pieces of the design that need to be connected in proper sequences and at precise locations in order to function properly. At the present time we cannot use the un-built shed for testing purposes so therefore an accurate model of the positioning of each device is critical. For example, when installing the sensor for the entry light, located on the rightmost wall, a ‘dead’ zone will need to be created to the right of the sensor. A window is located on the right side and if it detects movement outside, the light will activate draining the battery. The sensor could be triggered by simply ruffling of tree leaves.

Additionally, understanding the circuit layout is important to convey to the other teams working on the shed (Construction, Water, and Solar). They need to be aware of the positioning of the objects as well as where the each wire or panel will be installed so structural alterations won't be required down the. Further, the client wished to have the interface (Raspberry Pi) with switches/touchscreen located on the right hand size upon walking. The client also wished to have the outdoor light directly next to the door on the outside and inside light in the centre of the room.

Prototype 2

The purpose of prototype II is to test one of the major subsystems that the shed will contain. Prototype II demonstrates that capabilities of the light system. The Raspberry Pi computer controls the entire automation aspect of the shed including the lights, sensors, water valves and door locking mechanisms. Prototype II consists of a PIR motion sensor connected to the Raspberry Pi which then can signal the activation of a green diode connected to the breadboard. The diode is used as proof of concept for the final prototype which will power a full sized 75 watt equivalent LED.

Figure 1 and 2: Raspberry Pi connected to a PIR sensor. The PIR sensor is triggered and power is sent to an LED.

When tested, motion was detected from over 4 metres away with the PIR sensor - more than sufficient for our purposes. The delay is <1 second which is also acceptable. Using the Python code, delay and sleep time was easily altered.

Figure 3: Access terminal of the Raspberry Pi enabling version Python3 code directly from a txt file.

Figure 4: Second test using 2 module 5 volt relays, connected to auxiliary 12v power supply. Water valve solenoid connected to relay as well as PIR sensor connected to the Raspberry Pi
Figure 5: Raspberry Pi GPIO pin layout.

Our second test included adding two additional components to our prototype: a relay and solenoid. The relay is fed by auxiliary power supplied from an outlet which then converts to a 12 volt converter. When the PIR sensor receives motion, it sends a signal to the Pi, which then activates the relay. The test was successful and the solenoid was activated. The green LED did not activate however, the problem is with the code which will have to be sorted out at a later date.

We unfortunately did not have access to the client prior to the testing of Prototype II. We seek to meet the client minimum a week prior to completing our final prototype.

Final Design - Prototype III

The purpose of prototype III is to test non-essential subsystems that the shed will contain. Prototype III demonstrates that capabilities of the door locking mechanism, buzzer and code running upon boot of the Raspberry Pi. Prototype III consists of a membrane keypad that activates when a password is input which then activates the lock on the door. If the password is incorrect a buzzer emits a high frequency sounds telling the user it is incorrect. When the password is correct, it emits a different tone telling the user the password is correct. The testing of door locking mechanism was successful.

Additionally, the code was modified to activate as soon as the Raspberry Pi is activated. The reason is because the user or client may not have access to a computer screen or display to navigate the Raspberry Pi. The code worked sucesfully. Additionnaly, for troubleshooting purposes, the code can be activated or deactivated as needed.

Finally, the next step is to complete the breadboard circuit into a soldering breadboard. The raspberry Pi has two 5v pins; however, we have five devices that use 5v. To circumvent we need to build a parallel circuit that provides power to all of them

Figure 1: Buzzer connected to breadboard.
Figure 2: Beginning of the soldering breadboard circuit.

Figure 3: Python script for running upon boot.
Figure 4: complete circuit.

Figure 5: Membrane keypad for inputing code to activate lock
Figure 6: Circuit with view of the terminals to provide power for all 12v devices

The auxiliary power provides power to each relay which is connected to a terminal in a parallel design. The auxiliary power drives power to two LEDs and three solenoid.

The major issue at this time is ensuring the circuit is correctly constructing. Almost all the GPIO pins on the raspberry Pi are taken and ensuring each one is connected is difficult and time consuming. A program we used is called Fritzing which allowed us to properly design the circuit diagram with less issues.

Figure 7: Fritzing image of the circuit diagram.

Before installing the system in the shed, the final design testing worked perfectly without fault. In order to install and run the system upon system boot, extra code needed to be imbedded (Figure 3)

When installed in the shed and all wires connected to each sensor and auxiliary system, the testing worked without fault - a complete success.

Constraints, Risks and Regulations

Our main concerns with this prototype was time, costs and engineering mechanics. Buying and purchasing all the necessary materials quickly enough without causing any unnecessary delays in prototype building was a difficulty. Our team had very different schedules and meeting on weekly basis for extended periods of time proved difficult. Using basic communication programs such as WhatsApp was essential in maintaining open and quick communication. Proper planning using the Gantt system also allowed us to assign tasks and ensuring each team member is delivering on current deliverables and objectives.

As a result of the comprehensiveness of the design, going over our budget was also of real concern, As per our proposed Bill of Materials, we are already topped on the amount we can spend. Additional expenses will have to be justified appropriately. Additionally, this does not include any miscellaneous expenses we might incur. With most design projects, there are often unforeseen costs. The cost of a fully automated system will not fit into the allotted budget of 100$. Thus, we have determined that it was better to automate everything as requested by the client and add on wherever possible, just to demonstrate the functionality of the design.

In order to properly implement our prototype, it will be essential to maintain effective coordination and integration of all 4 systems of the shed (i.e. Automation, Water, Construction, Solar) especially in the in the final stages of design. Each system works in sync to serve the client. Ensuring the coordination between teams will be vital. Keeping open and constant communication on a bi-weekly basis will ensure all teams are on the same page.

One of our main concerns with this prototype is time. Primarily from purchasing all the necessary materials in a reasonable amount of time. Some of the components will be purchased internationally for cost-reduction purposes. It will be important take into account shipping time with these items. Second, ensuring we organize the team appropriately in the construction/design and to ensure our schedule meets the outline in our Gantt chart. Our team has very different schedules and therefore meeting on weekly basis and for over an hour is difficult. Proper planning using the Gantt system will allow us to assign tasks and ensuring each team member is delivering on time.

Since our design is fairly comprehensive going over our budget is a real concern. As per our proposed Bill of Materials, we are already topped on the amount we can spend. Additionally, this does not include any miscellaneous expenses we might incur. With most design projects, there are often unforeseen costs.

Automation specific constraints:

- Money constraint: We are operating on a limited budget of 100$

- Simplicity: The user interface cannot be excessively complex, as the users themselves are not necessarily familiar with more complex UIs. The components of the system as a whole must also be simple and easy to fix. As the user will likely have no access to somebody who can provide a trades service.

- Wires cannot cross from wall to wall:The walls of the shed should be able to be taken apart and as such the wiring of the automated devices cannot go through multiple walls because if they did, the walls in question would be inseparable.

Risks:

- Legal: Design must meet standards outlined in the Canadian Electrical Code (CSA C22.1) which pertains to the maintenance and installation of electrical systems. For the safety of the client, these standards are obligatory.

- Short Circuit: Having the current travel through an unintended path may cause harm to surrounding equipment/ people via overheating, and potentially even a fire.

- The damaging of other electrical equipment: The users do not have access to anybody who has experience in the trades, and those broken equipment may be difficult to deal with. Therefore, the circuitry must be carefully constructed by preventing such scenarios form occurring (i.e the overheating of certain equipment)

- Electrical Shock: The standard safety precautions and requirements must be met, otherwise the users' safety may be compromised. Electricity can be fatal.

- Electrical Fire: An electrical fire can occur for a number of reasons(e.g a short circuit), and the safety standards must be followed to prevent the occurrence of such an event.

Prototype Strategy and Results

The prototype strategy is based on the individual documents outlined in our prototyping test plan. Please see appendix for more details.

Conclusion

The overall design was a major success in all aspects. Every step of the design was planned meticulously and followed the prototyping test plan. The client was more than satisfied with the design which was the ultimate goal of the project. Some significant obstacles impeded the design process; however, workarounds were successful at achieving each of our outlined objectives. Additionally, other non-essential components were added to the design for added quality.

The takeaways from this process relates directly to the constraints we identified early on in the design process. For time, we may have been overly ambitious in determining how much time a task would take to complete. For the most part, solving certain coding and electrical problems took longer than expected which pushed our design plans back. In terms of time, forgetting simple materials or supports such as screws, bolts, and tape cost us valuable time in purchasing the additional materials. Lastly, because of the nature of our design, we were unable to install our devices until the other shed teams complete their work. Better planning with the others teams would have been ideal In summary, the lessons and experiences we learned are extremely valuable. We hope to apply the skills we learned in our future projects and academic careers.

Appendices

A. Budget

B. GANTT Chart