GNG 2101 Z- Intro. To Product Dev. and Mgmt. for Engineers

Final Report

Summer 2019

TactoMap

Submitted by:

[Group Z3]

[Audrey Igihozo, 300040534]

[Christian Boskovic, 300002301]

[Hanguang Huang, 8701167]

[Karl]

[Mika 300002413]

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Abstract

The goal of this project was to learn about engineering design techniques and how to work with a client. The client we were presented with worked in the Canadian government in accessibility. Our client wanted a tactile map designed for visually impaired people to navigate the first floor of 785 Carling Avenue. The specific location of 785 Carling avenue was chosen because the government had installed three accessible board rooms and needed a way to quickly direct visually impaired guests to these rooms. The secondary feature of the map would be to also show these guests where the washrooms, emergency exits and elevators are. Our first steps were to consult with our clients to find the desired specifications of the project. Once we understood the basic needs of our clients we started working on prototypes. The first prototypes were made of cardboard, to find the correct sizing of the map. But through iterative design we were able to adjust our design to our clients needs. We initially were working for a portable map, but decided to change our design to a stationary map design after consulting with blind clients and learning that a portable map wasn't possible for someone who used a cane. Our final solution was a stationary map with an electronic legend, with a series of buttons that would explain what their corresponding 3D printed map icons represented in French and English. The final product that we designed was satisfactory to our expectations, but further improvements would allow for the product to become more useful for more broad applications.

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List of acronyms

Acronym	**Definition**
MDF	Medium density Fibreboard

Table 1: *List of acronyms*

Introduction

The problem presented to us is that visually impaired people who are visiting the government building at 785 Carling Avenue are having trouble navigating to the accessible conference rooms. This is important for many reasons, the largest reason is that the government has used their resources to create a space for people who cannot easily access it. For the space to serve its function there needs to be some assistance for the users to navigate the building. There is also a moral obligation for both the government and engineers to use their power and means to create good in society. Working with visually impaired users to help them navigate and function in the world easily and with dignity is simply a moral thing to do. Finally, there is a serious safety risk in case of a fire or other emergency if visually impaired people do not know where the emergency exits are.

After understanding the key reasons why we are working on this project we can move on to the basic user requirements. We must design a product that addresses those concerns of the client. Firstly, we need to allow visually impaired people to find a path to the conference rooms. Secondly, we need to keep the map discrete and elegant to make the solution as dignified as possible for our users. Finally, we should label emergency exits and washrooms for the users.

Our final design has the advantage over competitors because its relatively inexpensive. This would allow future clients to be able to afford these devices as well. This would also allow clients to install multiple maps in a building to allow for users to navigate from different points. Our design is very elegant and simple, it won't be an eyesore for non visually impaired users. Also our design functions without a mobile app or any required technology, this means that any visually impaired person would be able to use our devices. Going to a stationary design from a portable design offers the accommodation for users with canes. Using an electronic legend allows for users who don't understand braille to use the product.

2. Engineering design process

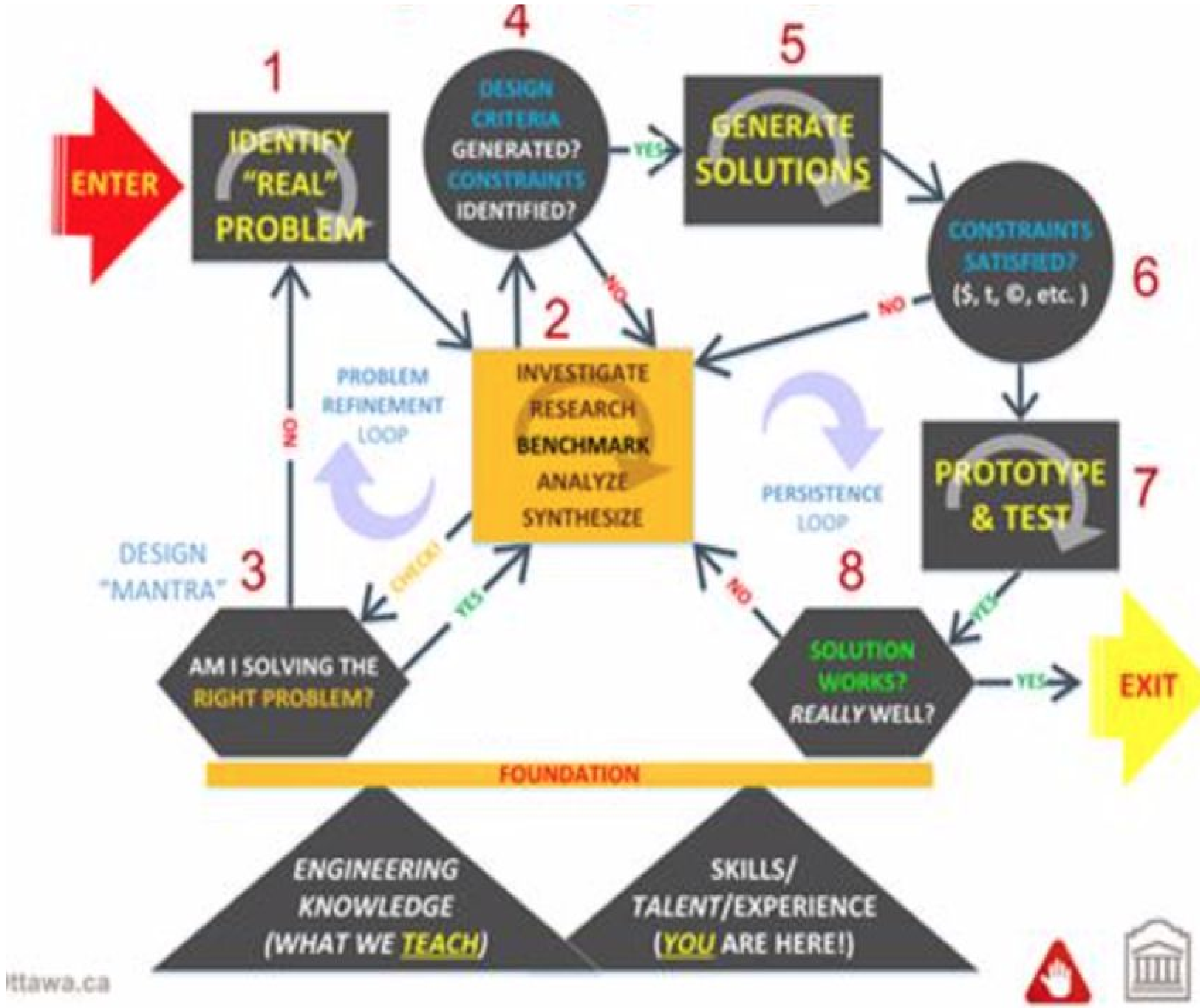


Figure 1: *Engineering design process model*

The team that the best process to utilize for our product development is Iterative Engineering Design Thinking method

3. Needs Identification and Benchmarking

a. **Problem statement:** The problem that our product is meant to satisfy is the issue of accessibility for people with visual impairments. Our solution will be in the form of a tactile map that will provide information about where the bathrooms, conference room and obstacles are quickly and simply.

b. **Benchmarking of similar products(**weakness and strength of competitor)
Purely Braille signage: Has the advantage of being very simple, easy to understand and easily produced. Some products like the *PrestoBraille signmaker* can produce braille signage very quickly with a commonly available product. But this technology lacks the ability to convey the locations of obstacles or the safe path to navigate a room. A map can convey a large amount of information very quickly compared to reading. Also, these printers can cost upwards of $3000, whereas 3D printers are more readily available cheaply. So these maps could be produced more cheaply.

Figure 2*: PrestoBraile Signmaker:*

Wayfindr: This is an app that uses the customer's cell phone to provide audio based directions for visually impaired persons. The advantage of this solution is that cell phones are extremely commonplace. The software is also being made to be very readily available at no/minimal costs. The biggest disadvantage to using cell-phones in this way is that they require audio to communicate with a visually impaired person, therefore requiring them to wear earphones and compromising their ability to hold a conversation or hear others.

Figure 3*: Wayfindr Ad from interaction awards:/*

C. A list of metrics with associated units

I. Weight (g) : If design selected is a portable map total mass should be roughly under 200g. If map selected is stationary weight is not an issue.

Ii. Size: length (cm), width (cm), height (cm): if map is portable approximate sizing should be near 25cm x 25cm. If map is stationary possibly 50cmx50cm or larger would be appropriate.

Iii. Cost: Target budget is $100

D. A set of target specifications

i) Materials: The materials we might use are, acrylic, plastic, MDF, and they are all durable and not that expensive compared to maybe metal or glass.

ii) Quantity: If we make portable maps, we will make more than one. If we produce one that will be hung, then it will be just one.

iii) Documentation/Training: The product will be easy to use, the instruction will be provided if any, and there will be a legend to help identify the items/symbols on the map.

iv) Testing: We will test the product to make sure it is efficient and meets all the clients needs.

v) Environment: The product will be produced on computer and in the lab.

vi) Patents: No need to license someone else's patent.

vii) Pricing: So far we haven't discussed the price because it will all depend on what materials and technologies we will be using.

viii) Competition: Another group in our section has the same project, and there has been previous tactile maps produced but not for this specific floor.

ix) Maintenance and repair: There are no special tools needed to repair the map, however because it is going to be touched all the time, the material might get old. We will make sure we use durable materials to avoid that.
x) Weight: Easy to carry and handle
xi) Size: Customer said it does not matter, but the bigger the better.
xii) Customer: This is the first time for this tactile map to be designed for the first floor, however tactile maps have been produced in the past. The user will not need any type of training to use the product.
xiii)Packaging: We have not specified what material will be used on the final product, however it will be fragile, therefore it is best to protect it during shipping.
xiv) Time-scale: The product will be on the market on July 15th, 2019.
xv) Product cost: The budget is $100, the target is not to go over that amount.

4. Conceptual Designs

Based on our customer's needs, we clarified core functionality by breaking down required product functions into smaller basic sub-functions, and identifying external sub-system boundaries and then each member came up with three concepts in order to generate one solution that will satisfy all the needs of our customers.

Audrey:

1. Use plastic to 3D print the small portable maps. It is cheaper and faster. The user can carry it around and then return it to the front desk. It is quite small and not confusing at all.

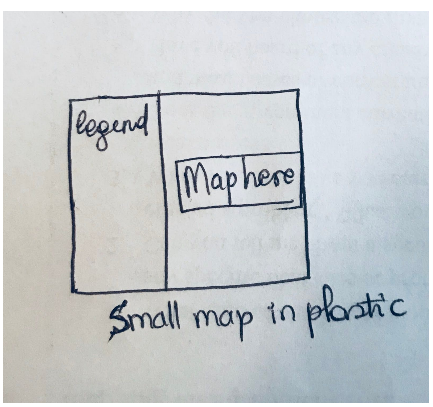


***Figure 4**: concept 1*

2. Use MDF wood to laser cut the bigger map for the main entrance. Cheaper than acrylic, smoother and lighter. It can't be transported, it is stationary.

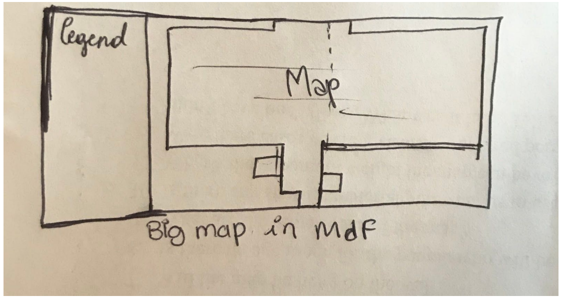


Figure 5*: concept 2*

3. Use acrylic glass and the laser cutter as well for the main entrance big map. This is almost the same idea as the previous one just more expensive and heavier, however it can last longer compared to the mdf.

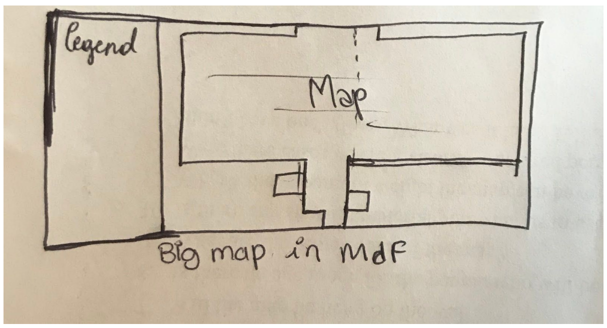


Figure 6*: concept 3*

Christian:

1. Use recycled plastic parts put together and painted over to ensure a smooth finish. Cheap and easily accessible materials would be something to consider. This would also be environmentally friendly.

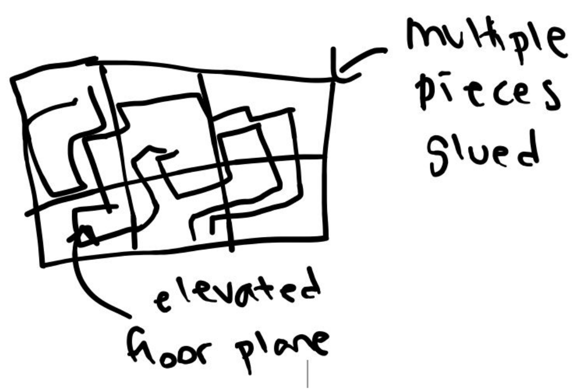


Figure *7: concept 4*

2. Using a 3D printer to print a topographic style map of 785 Carling. This machinery is easily accessible and inexpensive for the group to use to make the final product.

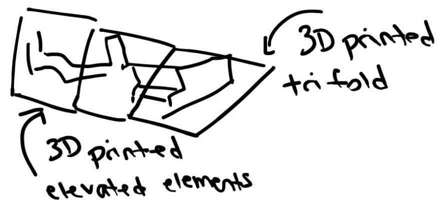


Figure 8*: concept 5*

3. A park map-style design, compared to the one in Major's Hill Park which shows a bird's eye view of the city in 3D. Ours would be made of sheet metal which is easy to manipulate, obtain and finish.

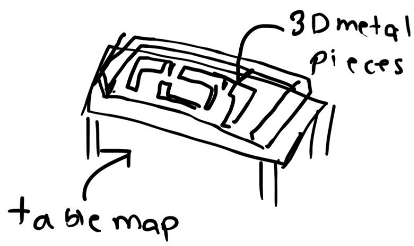


Figure 9*: concept 6*

Huang:

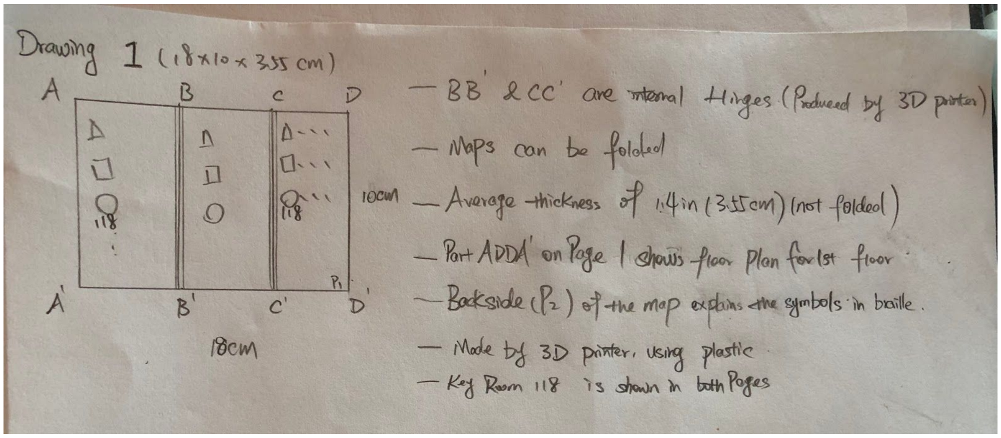
1. 

Figure 10: *concept 7*
Double Hinged map （3D printing)

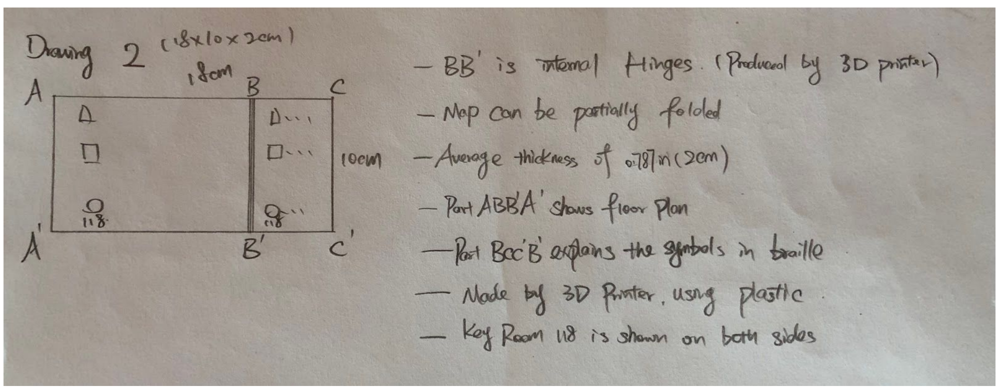
2. 

Figure 11: *concept 8*
Single Hinged map (3D printing)

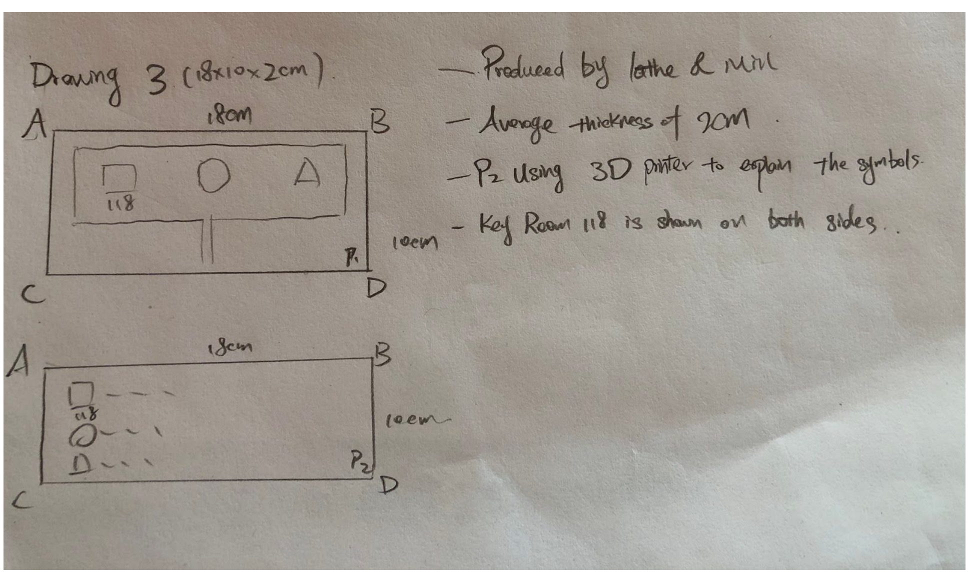
3. 

Figure 12: concept 9
Lathe and Milling process & 3D printing:

Karl:

1. Use mill on solid block of wood (poplar wood) for a large map in the hallway. The block of wood is heavy; however, it will be a solid piece that will last virtually forever. This option will cost more and cannot be carried around; thus, this concept has its setbacks.

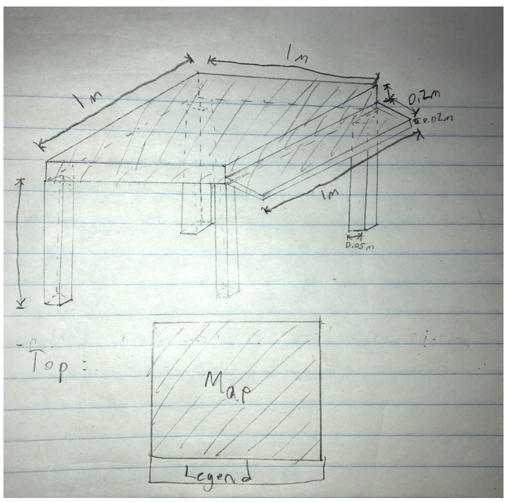


Figure 13: concept 10

2. Smaller maps printed by 3D printer that can be disposable, one map for the floor plan and other detailed maps of important rooms can be made.

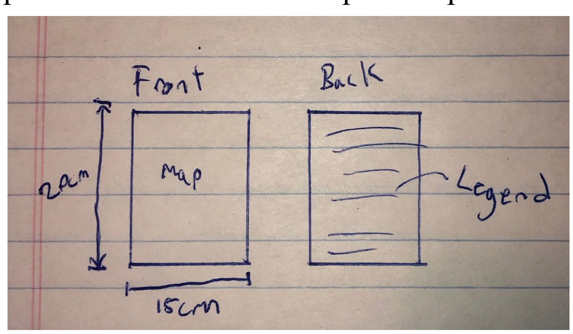


Figure 14: concept 11

3. A foldable map which is 3D printed, can be made containing the essential accessible room and route to accessible conference room.

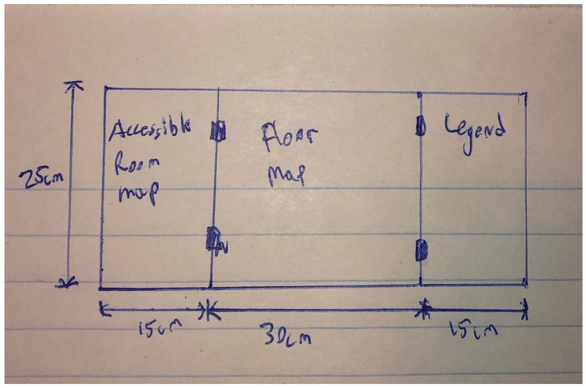


Figure 15*: concept 12*

Mika:

1. Large tabletop map made from multiple smaller 3D printed tiles.

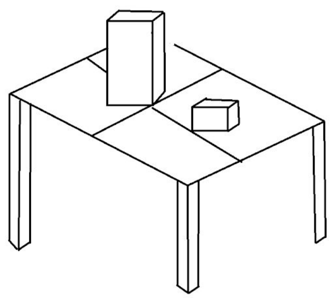


Figure 16*: concept 13*

Would be made of a table and 4 tiles measuring at 20cmx20cm. This would be placed near the entrance of the building.

2. A folding book style map made from two 3D printed pieces being held together by a hinge.

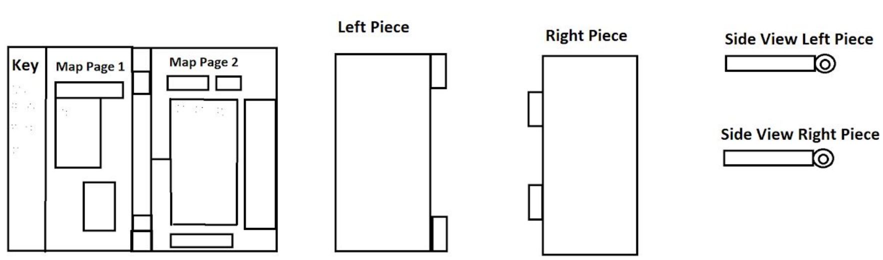


Figure 17*: concept 14*

3. A small, simpler map used in conjunction with a series of beacons that interact with the client's cell phone.

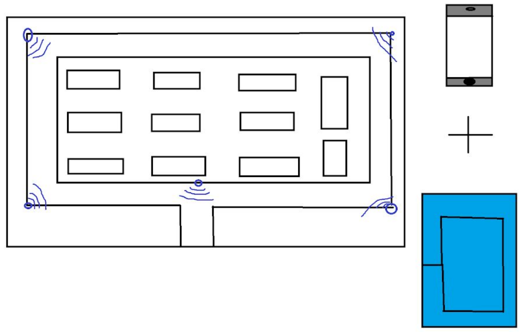


Figure 18*: concept 15*

From the evaluation, concept B from Mika's design has the highest score, it has well performance at listed five aspects. Thus, group chose Mika's design B for further development.

5. Project Planning and Feasibility Study

Task list, task ownership and task deadlines:

#	Task name	Task owner	Required resources	Completion deadline
1	Conceptual design + project plan	Everyone	Trello	June 2, 2019
2	Detailed Design and Prototype 1	Everyone	Cardboard Tape Solidworks	June 2, 2019
3	Project Presentation	Everyone	-	June 9, 2019
4	Business Model	Everyone	-	June 16, 2019
5	Prototype II and customer feedback	Everyone	-3D printer -Nuts&bolts	June 23, 2019
6	Economics Report & 1 minute video	Everyone	-Computer Lab	June 30, 2019

7	Design Day Materials + Prototype 3	Everyone	-	July 14, 2019

Table 2: *Initial planning table*

Gantt Chart:

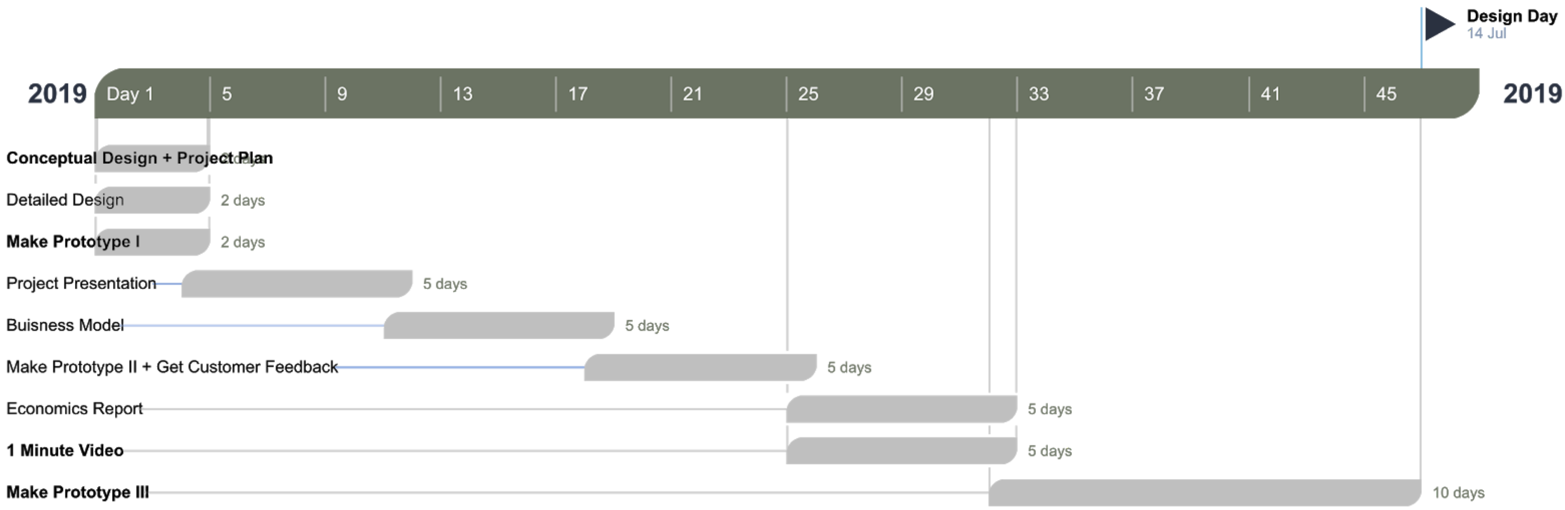


Figure 19: *Gantt chart*

Feasibility study: To provide strengths and weaknesses of solution based on TELOS factors

Technical: Our team does have enough expertise and technical resources to successfully complete this project. Our team is comprised of people with many different skills across a handful of engineering disciplines. We have people who know CAD, creative sketching, time management, and budgeting skills.

Economic: The cost of our project can be very reasonable. We do not anticipate it reaching or surpassing the 100$ limit. Most, if not all, of our prototypes are expected to be free of costs.

Legal: As of yet, there seems to be no legal issues with releasing our solution to the public.

Operational: The only true operational constraints that would prevent our group's success is finding and allocating time outside of designated class and lab times to work on this project. Our group members have busy lives outside of school which include work, extracurriculars, co-ops. Finding time is a small issue, but we have solutions to succeed.

Scheduling: The product deadline is July 15th, 2019. The summer session is shorter, therefore the deadlines are not that reasonable, because we had to work harder to reach the goal in such a small period of time.

Final Bill of Materials

Item #	Name	Description	Quantity	Unit cost	Extended cost	Link
1	Arduino UNO R3	Microcontroller, with input/output pins, which will control the speaker, and the buttons	1	$17	$17	Makerstore
2	breadboard	It is solderless and can be used for prototype 2 and 3 to connect circuits and test them with arduino	1	$2.50	$2.50	makerstore
3	Mini speaker	Mini hamburger speaker rechargeable with extension cord	1	$22.49 Or $13.98	$22.49 / $13.98	https://well.ca/products/kikkerland-blue-micro-speaker_157009.html?gclid=EAIaIQobChMIzNjK8ff14gIVwh-GCh2hPATfEAkYBiABEgJr7vD_BwE

						Or https://www.amazon.ca/Speaker-Portable-Pillow-Exquisite-Appearance/dp/B07QL47V48/ref=sr_1_5?keywords=portable+speaker&qid=1560969462&refinements=p_85%3A5690392011&rnid=5690384011&rps=1&s=gateway&sr=8-5
4	Battery	We haven't decided which batteries to use	-	--	-	makerstore
5	SD Card Module	MicroSD card breakout board+	1	$7.50	$7.50	https://www.adafruit.com/product/254
6	Mdf wood	18in x24 in for the map	1	$4	$4	makerstore
7	Jumper cables	To connect and solder the circuits	20	$1 for 10	$2	Makerstore
8	Push buttons	Tactile push switch(6mm)	20	-	$5	Makerstore
9	protoboard	Snappable PC breadboard	1	$7.60	$7.60	https://www.amazon.ca/BusBoard-P

						rototype-Systems-SB4-BreadBoard/dp/B00PKVSQX2/ref=sr_1_3?crid=3P95KAZZIRNTY&keywords=protoboard&qid=1560985520&refinements=p_85%3A5690392011&rnid=5690384011&rps=1&s=gateway&sprefix=proto%2Caps%2C162&sr=8-3
10	3D printing PLA				$0	Makerspace
11	Soldering				$0	Makerspace
12	Laser cutting				$0	Makerspace
13	Paint			$0	$0	Makerstore
Total					$59.58	

Table 3: *Bill of materials*

6. Analysis

Analysis table (rate out of 10)

Property	Importance (weight)	Audrey(a)	Christian(b)	Peter (b)	Karl(a)	Mika (b)
Size	0.4	8	7	7	8	8
Cost	0.3	7	9	9	8	9
Complexity	0.2	4	5	5	7	5
Durability	0.05	3	2	4	5	4
Aesthetic	0.05	5	5	5	8	7
Sum (/10)	---------------	6.50	6.85	6.95	6.60	7.45

Table 4: *Concept analysis (ratings)*

7. Prototyping, Testing and Customer Validation

1. Prototype I

Figure 20: *Prototype I*

We had a small mock-up prototype earlier which was two pieces of cardboard attached via a small plastic string. This was made to show the client what size we wanted to make the final design to give him an idea of what the dimensions will be.

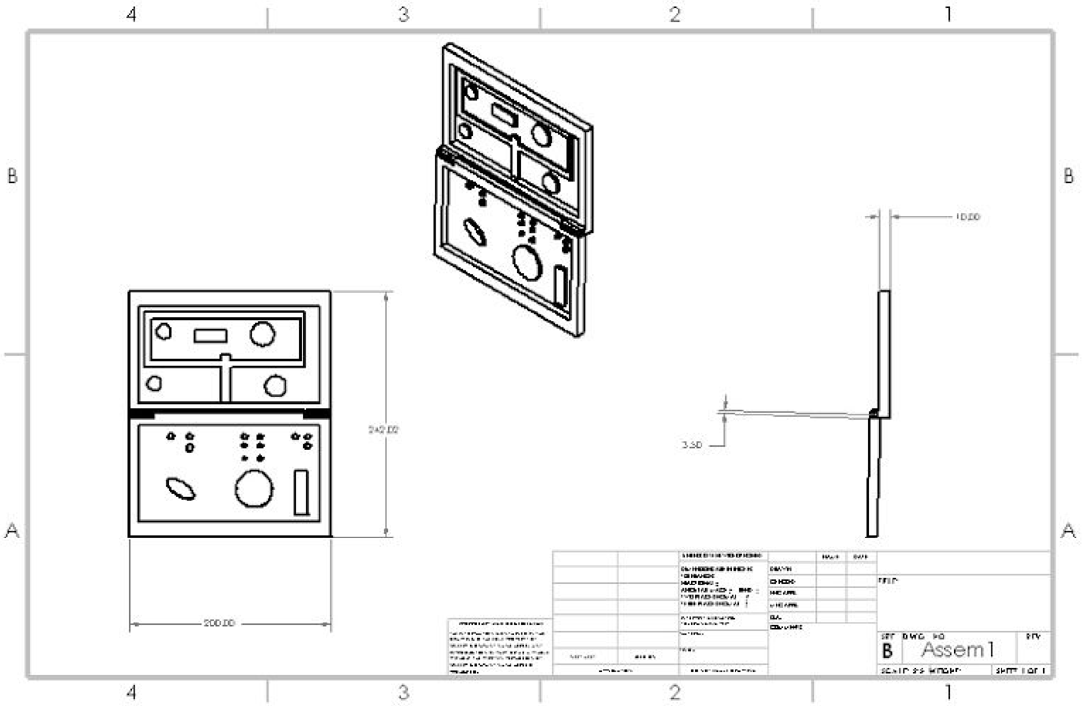


***Figure 21**: Top view in 3D*

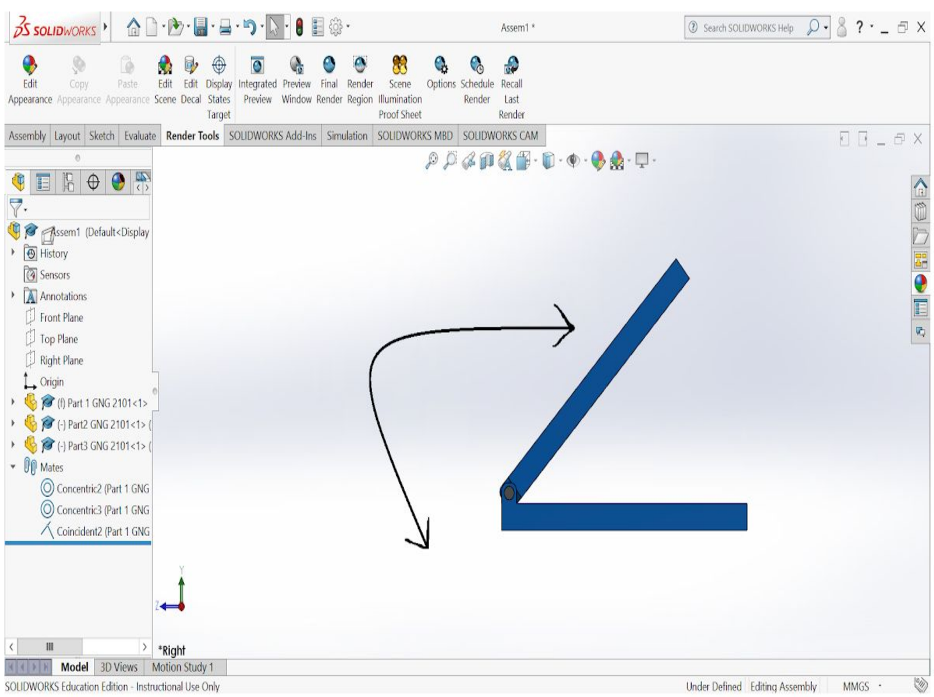


***Figure 22**: Side view in 3D*

Target specification (from deliverable B)	**Status**
Materials: The materials we might use are, acrylic, plastic, MDF, and they are all durable and not that expensive compared to maybe metal or glass.	
Quantity: If we make portable maps, we will make more than one. If we produce one that will be hung, then it will be just one.	**same**
Documentation/Training: The product will be easy to use, the instruction will be provided if any, and there will be a legend to help identify the items/symbols on the map.	**same**
Testing: We will test the product to make sure it is efficient and meets all the clients needs.	Due to the nature of our prototype being of the software kind, there is no way for us to test its functionality as of yet. We anticipate on carrying out various types of testing and client handling with the progression of our design; when it turns into a physical model.
Environment: The product will be produced on computer and in the lab.	**same**
Patents: No need to license someone else's patent.	**same**
Pricing: So far we haven't discussed the price because it will all depend on what materials and technologies we will be using.	Still needs to be determined
Competition: Another group in our section has the same project, and there has been previous tactile maps produced but not for this specific floor.	**same**

Maintenance and repair: There are no special tools needed to repair the map, however because it is going to be touched all the time, the material might get old. We will make sure we use durable materials to avoid that.	**same**
Weight: Easy to carry and handle	We need to take extra care to make it holdable with one hand
Size: Customer said it does not matter, but the bigger the better.	It actually needs to be the smallest possible, the biggest change based on feedback
Customer: This is the first time for this tactile map to be designed for the first floor, however tactile maps have been produced in the past. The user will not need any type of training to use the product.	**same**
Packaging: We have not specified what material will be used on the final product, however it will be fragile, therefore it is best to protect it during shipping.	**same**
Time-scale: The product will be on the market on July 15th, 2019.	**same**
Product cost: The budget is $100, the target is not to go over that amount.	**same**

Table 5*: Prototype I Testing*

2. **Prototype II**

Our second prototype was heavily upgraded in comparison to the first one - which was simply two pieces of cardboard held together by a string and some CAD designs. We decided to keep the size of the prototype the same as the original; however, we upgraded the material from cardboard to a more sturdy and durable MDF board. We also decided to 3D print multiple small pieces as guides to place on the map - which proved effective at our client meet. We took the notes of trying to include audio in our design by having our team members create a basic code and test it; to see whether or not it was possible.

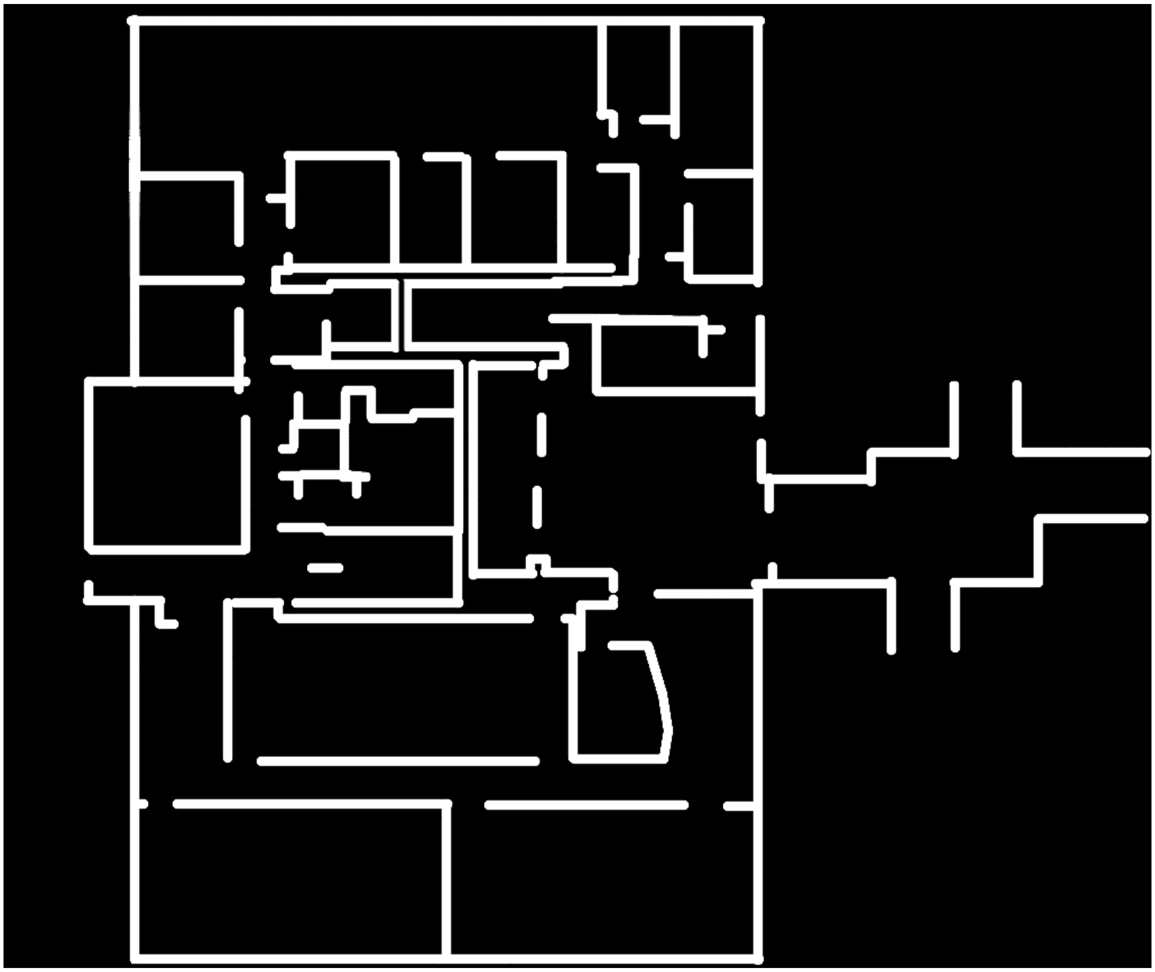


Figure 23: *Prototype II*

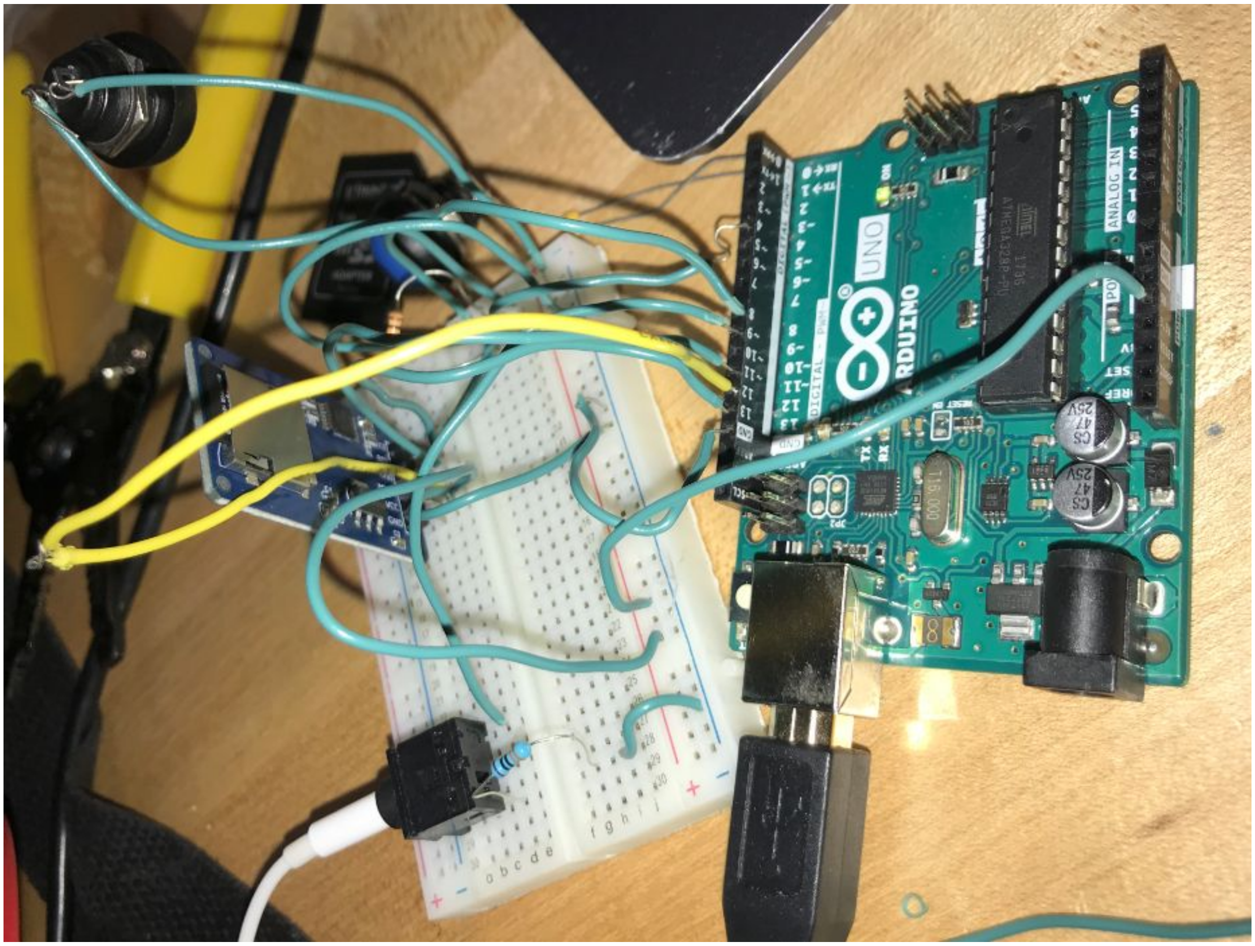


Figure 24: *Prototype II circuits*

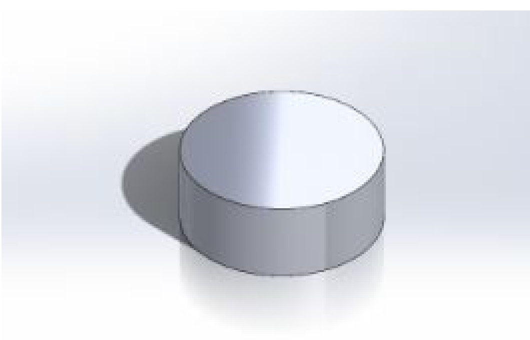


Figure 25: *the circle was to represent the pathway*

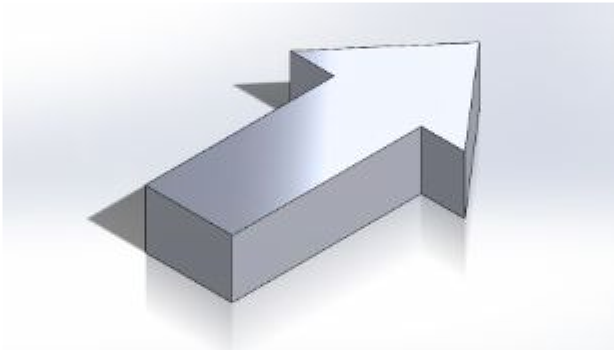


Figure 26: *Arrow to represent emergency exits*

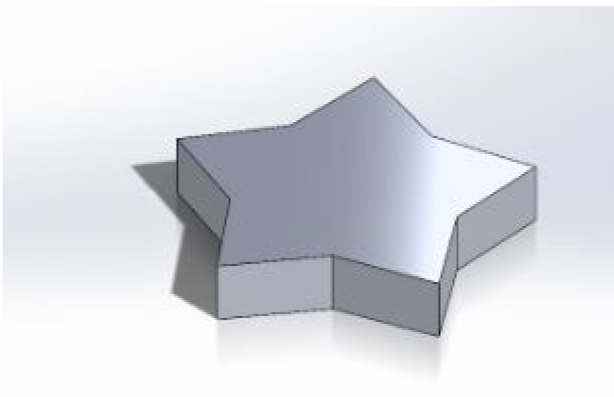


Figure 27: *a star to represent where you are in the building*

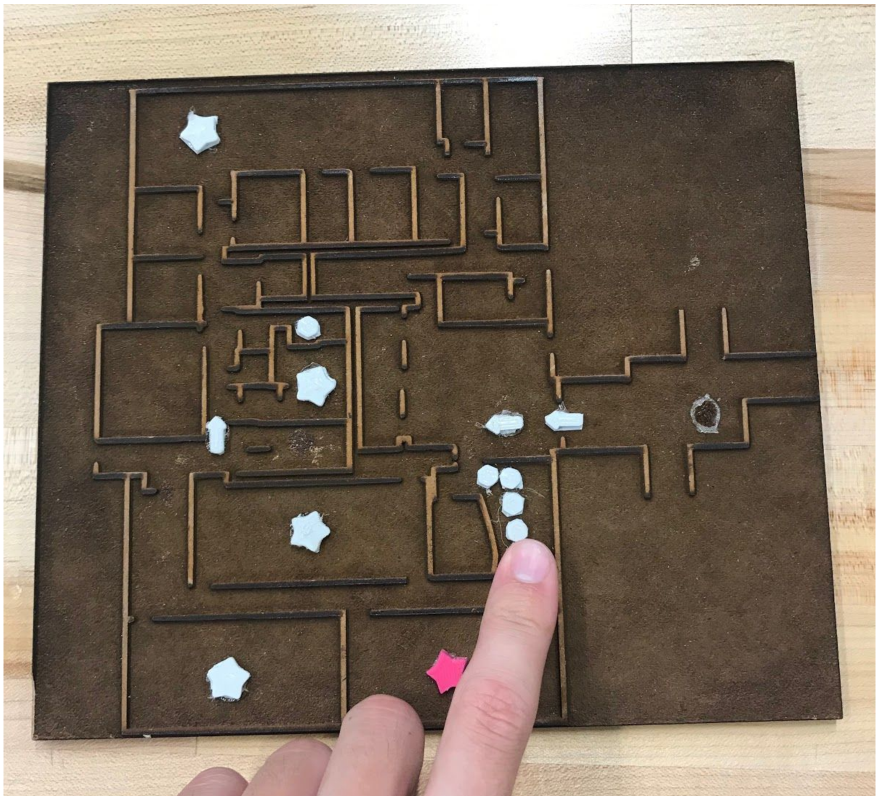


Figure 28: *Prototype II picture*

Prototype II had no legend or audio components at that point, which was then implemented in further prototypes. Prototype did not distinguish washrooms, staircases and emergency exits yet.

3. Prototype III

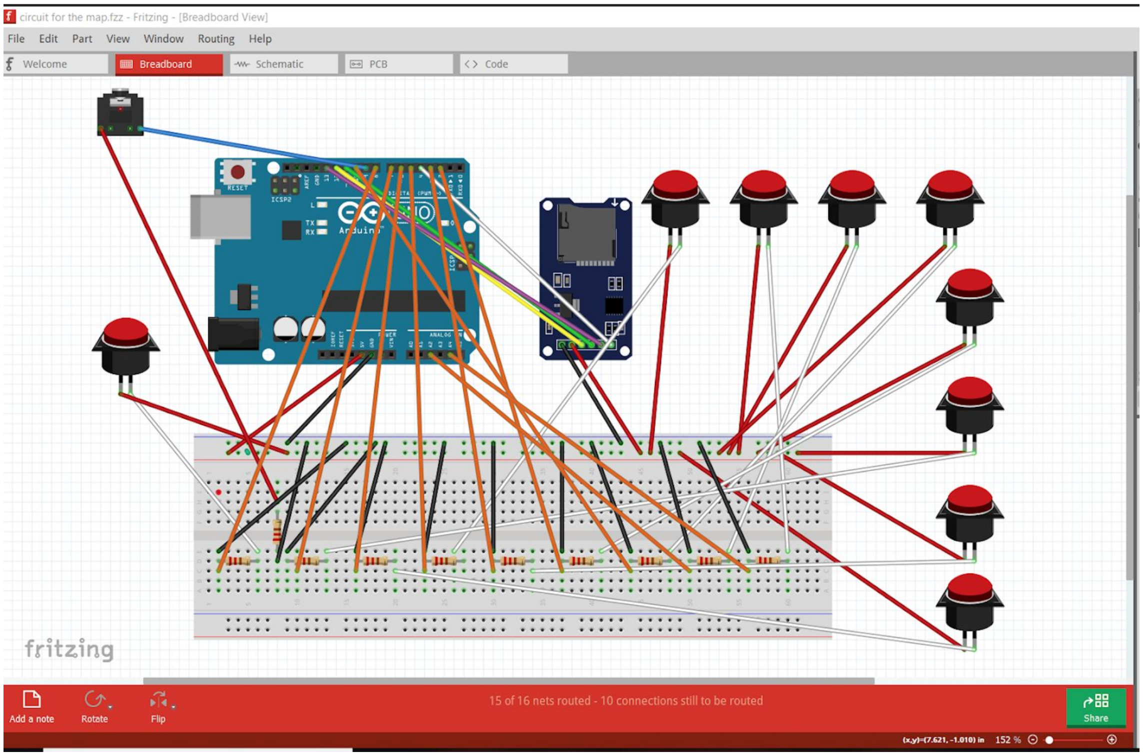


Figure 29: *Circuit of prototype III*

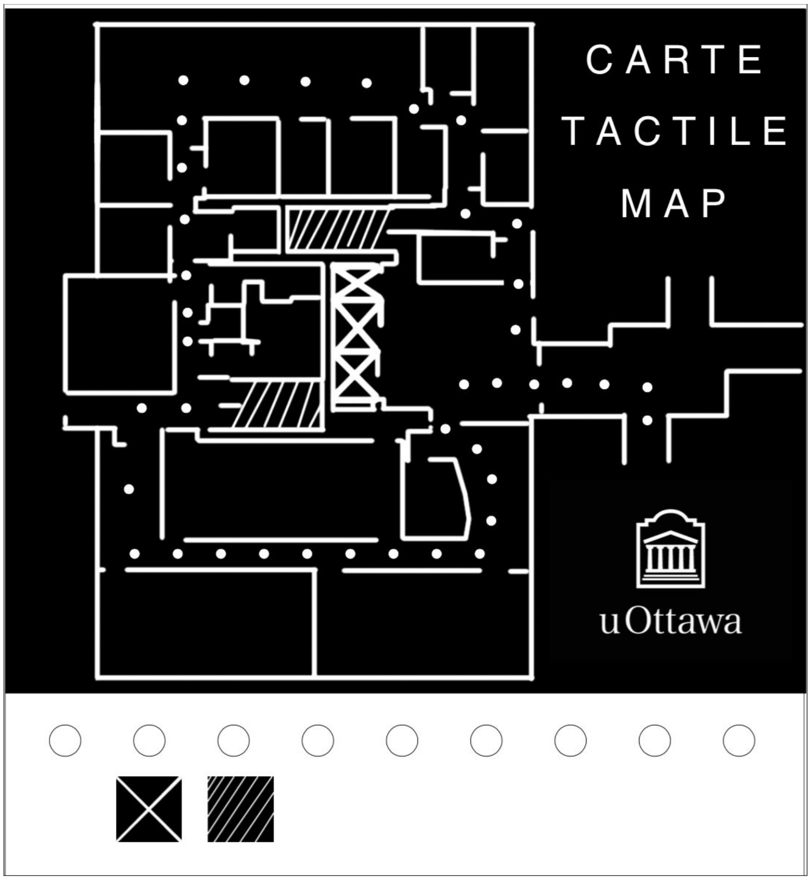


Figure 30: *final prototype on inkscape*

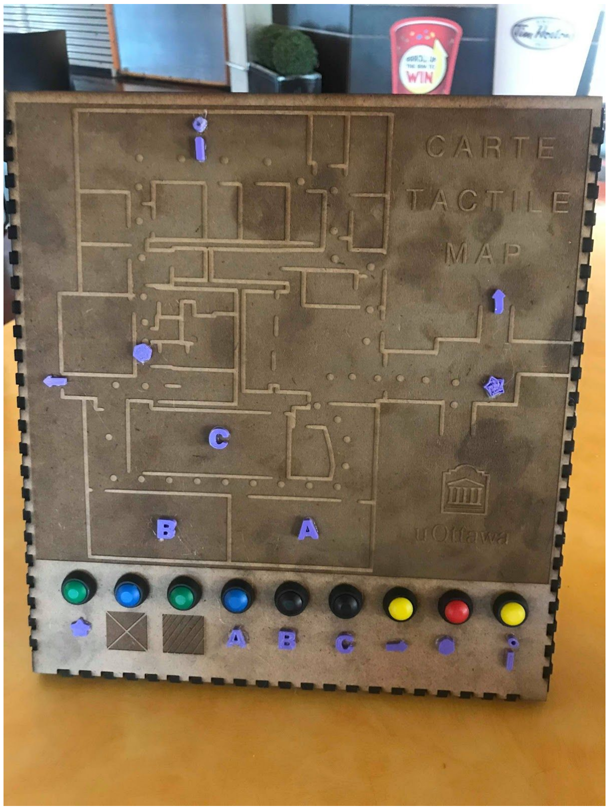


Figure 31: *Final prototype (front view)*

Figure 32: *final prototype (side view)*

8. Final Solution

Our final product design is our third prototype, as would look and operate exactly the same as it did on design day. Since the course has come to an end and we no longer have access to the labs in STEM, we did not have the time to produce our "final product" for show. If we did, the laser cutting would be twice as deep on the MDF to provide a more defined tactile feel to the map. We would also colour the board to provide contrasting colours, such that those who are partially visually impaired could distinguish the shapes. Our third prototype present one tactile map unit that can be implemented in the building. Our vision of a final solution to the problem incorporates multiple maps throughout the building. Our design allows the map to be hung on walls and be very placeable on small stands and tables. The audio system could be loaded with anything, and be programed to give specific directions at different points of the building to users. This way our final solution can best meet the needs of the visually impaired.

9. Business Model

The most viable type of business model for our product would be the **brick** and **mortar model**. Since we are selling custom designed physical goods, we cannot realistically use freemium, advertising or subscription based models. The razor-blade model would be slightly applicable, but that would apply more to the manufacturing of the maps more than the designing of them.

Our company will be modelled more as a consulting firm to design custom maps for building owners. Having a traditional brick-and-mortar style operation would give us space to design, manufacture and meet with clients. For the purpose of the course the Maker Lab will act as our company space.

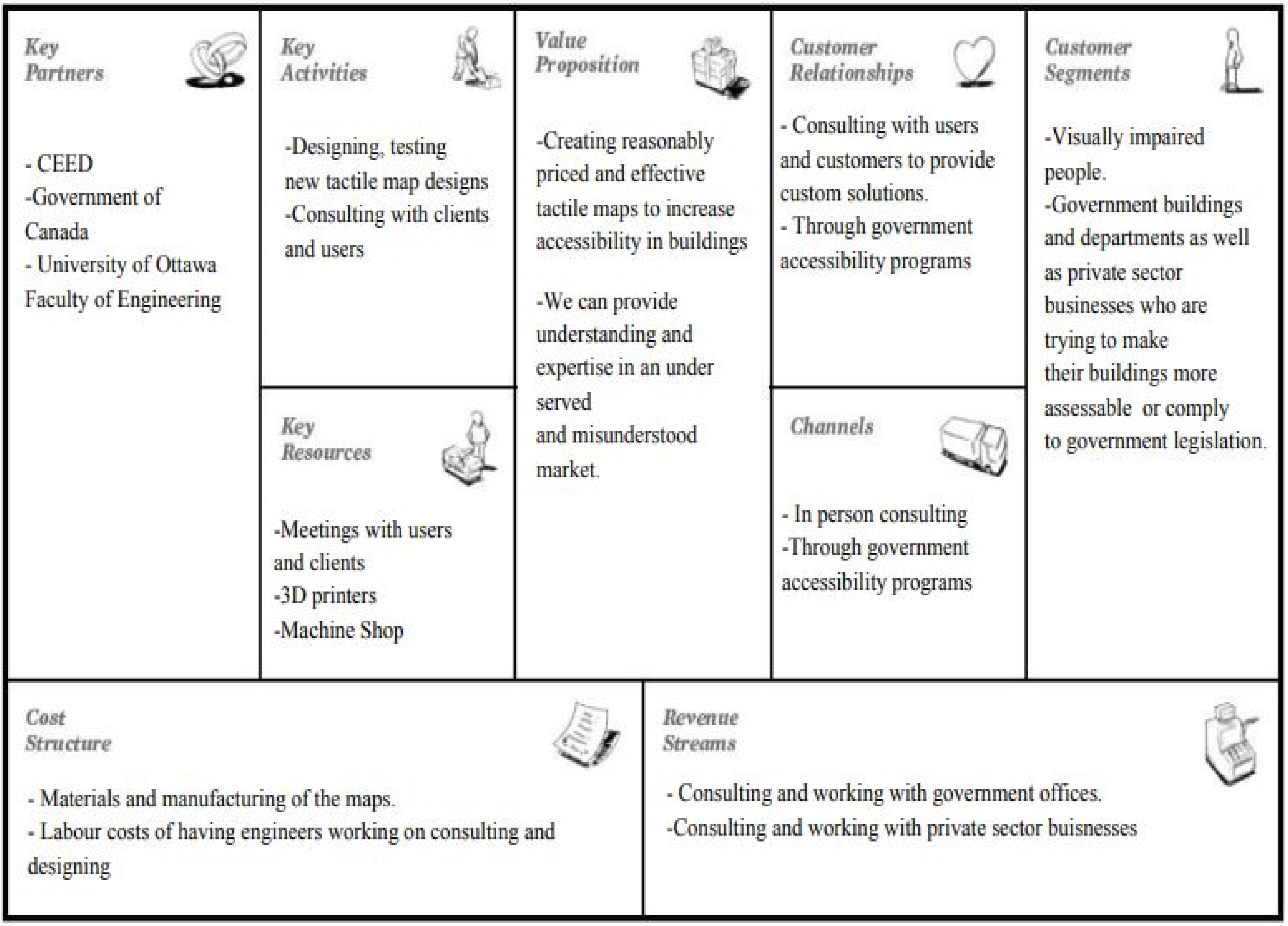


Figure 33: Business model canvas

These are the assumptions that the team had made in developing the business model.

- *Financial Assumptions*: We are being provided with a strict 100$ cap to spend on the entire project (mostly to be allocated to the final prototype)
- *Resource Assumptions*: We can expect all the resources that are provided by the makerspace.

- *Schedule Assumptions:* Our schedule is based on our Gantt chart, which has a final work day at design day.
- *Customer Assumptions:* Our only initial "customers" for this project are our client - Graham - and the people he works alongside in the government.
- *Competition Assumptions:* Only another group is competing with our design, there is no other local attempts to solve this problem.
- *Technology Assumptions:* We are using mostly solidworks to design the map and then print it with 3D printer ultimaker 2+
- *Marketing Assumptions:* Our project is focusing on clients with visual impairment, and a price under 100$.
- *Facility Assumptions:* The entirety of this project will be made within the University of Ottawa campus facilities including MakerSpace and MakerLabs, as well as within the office spaces of 785 Carling Avenue.
- *Procurement Assumptions:* Our project is fully based on 3D printing which can be found on campus, and it is free to students.
- *Compliance and Regulatory Assumptions:* Our project is fully tested by our team and client - Graham.
-

10. Economic Analysis

Classification of Cost

Type of Cost	Description of Cost
Variable Cost	Our variable costs are costs which vary with the production output level. Since our production output level is very low, we do not

	anticipate having many variable costs. An example of a potential variable cost would be the amount of acrylic or MDF used in the production stages.
Fixed Cost	Our fixed costs would be the costs which are independent to the production levels. An example of a fixed cost would be the cost of potential purchases of software licences or 3D printers (again, hypothetically if we became a real business and did not use materials provided by the University).
Direct Cost	Our direct costs are variable/fixed material/labour/expense costs for the specific project. As of yet, we have no labour costs. The purchasing of acrylic boards, Arduinos + accessories, and all other electrical components count as direct costs.
Indirect Cost	Our indirect costs are variable/fixed material/labour/expense costs independent of specific projects. Some indirect costs of our project could be "paying" the project manager if we were a real company functioning within the University labs.

Table 6: *classification of cost*

Income Statement for 3 Years

An income statement is an explanation of the change in wealth of a company/organization over a specified period of time. Another term for income statement is "Profit and Loss" statement including asset values. Income statements are used to determine how profitable a business is. A basic income statement shows: sales (revenues) - expenses = profit/loss. In this deliverable, we're asked to develop a 3 year income statement for our company. The easiest way to do this would be to display the information annually.

<u>Annual Gross Profit Calculation:</u>

Sales (revenue) - Cost of goods sold = Gross profit

(50 units x 100$/unit) - (50 units x 55$/unit) = 5,000$ - 2,750$ = 2,250$/Year

Annual Gross Profit in 3 years is 2250 * 3 = 6750$

<u>Annual Operating Income Calculation:</u>

Gross profit - Operating expenses = Operating income

2,250$ - (marketing expenses + general and administrative expenses + depreciation expenses)

2,250$ - (0$ + TBA + 0$) = 2,250$

Annual Operating Income in 3 years is 6750$

Marketing Expenses = In the first 3 years, our business anticipates 0$ in marketing expenses by relying on word-of-mouth referrals within the government system. We also anticipate on making our own promotional videos until we are more well established.

General and Admin Expenses = Our business will be starting off working within the residences of our founding members to eliminate any expenses of that sort. However, we would anticipate buying some equipment such as rental/lease of 3D printers and laser cutters/or membership to makerspaces within the University of Ottawa. These costs are unknown as of yet due to needing an application to the space before receiving a quote.

Depreciation Expenses = Since our business will not be buying any equipment of our own we will not be anticipating any depreciation costs.

Earnings Before Taxes Calculation:

Operating income - Interest expenses = Earnings before taxes

2,250$ - (5,000$ x 0.04) = 2,250$ - 200$ = 2,050$

Earning Before Taxes in three years is 6150$

Interest expenses = Our business anticipates taking out a hypothetical loan from the bank of 5,000$ at an interest rate of 4%. This loan will be taken to ensure the company stays afloat in the first 3 years. This loan will be a one-time move.

Net Income Calculation:

Earnings before taxes - Income taxes = Net income

2,050$ - (25% x 2,050$) = 2,050$ - 512.50$ = 1,537.50$

Net income after tax in 3 Years is 4612.5$

Income taxes = Using the model provided by the professor in our lecture, we will be using an example income tax rate of 25% to compete our business model.

Our Completed Annual Income Statement for 3 years:

Income Statement for Carte Tacto Map:

Sales: 15000$

Cost of Goods Sold: 8250$

Gross Profit on Sales: 6750$

Operating Expenses:

Marketing Expenses //

General & Admin Expenses //

Depreciation //

Total Operating Expenses: 0

Operating Income: 6750$

Interest Expense: 600$

Earnings Before Tax: 6150$

Income Tax (25%)

Net Income: 4612.5$

Break Even Point Determination

BEP = The point where total cost and total revenue are equal:

Fixed cost such as 3D printers purchased by non-UOTTAWA organization would be 550$ (Price data collected from Amazon)

Sale price per unit: 100$

Variable cost per unit: 55$

BEP(per unit)= Fixed Cost/(Sale price per unit - Variable cost per unit)

BEP= 550/ (100-55)=13 units

Therefore, the breaking point for our product is 13 units.

11. Conclusions and recommendations for future work

To conclude, the final product we made was satisfactory generally but there were some changes that were made to accomodate manufacturing times that would not be in the product in an ideal world. Firstly, the final product was made from MDF board, this was due to severe warping in our acrylic sheets during laser cutting. With the correct amount of time an acrylic product would be superior. The black background of a sheet of acrylic would allow for a larger contrast between the 3D printed icons in white and the map. There is also a very strong smell of MDF board which is not desirable in the final product. We also had our arduino fail in our product, in an ideal world we would be able to have a fully functional electronic legend. Another change to the legend would be for the map to tell the user specialized routes to the location of the button they just pressed for example: *conference room A, take a left, walk 10m, take another left through the door then walk 10m then take a right, the conference room will be on the left*.

In terms of applications, having a series of slightly different maps in terms of the location of the *you are here* and the paths would allow for users to navigate the building more easily. This is because the solution of only having one map requires the user to memorize all routes and the whole layout of the building.

Another improvement to the application of our product would be to include the options for clients to have a battery pack and wall mounts. This would allow the clients to mount the maps wherever they would need them.

12. Bibliography

Code:

```
tactilemap_code §
#include <SD.h>                       // need to include the SD library
#define SD_ChipSelectPin 4            //  using digital pin 4 on arduino nano 328
#include <TMRpcm.h>                   //   also need to include this library...

TMRpcm tmrpcm;                    // create an object for use in this sketch
 int SW1;
 int SW2;
 int SW3;
 int SW4;
 int SW5;
 int SW6;
 int SW7;
 int SW8;
 int SW9;


void setup(){
 pinMode(8,INPUT);    //Define A0 as digital input.
 pinMode(2,INPUT);    //Define A1 as digital input.
 pinMode(7,INPUT);    //Define A2 as digital input.
 pinMode(10,INPUT);   //Define A3 as digital input.
 pinMode(A0,INPUT);   //Define A0 as digital input.
 pinMode(A1,INPUT);   //Define A1 as digital input.
 pinMode(A2,INPUT);   //Define A2 as digital input.
 pinMode(A3,INPUT);   //Define A3 as digital input.
 pinMode(A4,INPUT);   //Define A2 as digital input.
 pinMode(A5,INPUT);   //Define A3 as digital input.
Serial.begin(9600);
Serial.println("start");

  tmrpcm.speakerPin = 9; //11 on Mega, 9 on Uno, Nano, etc

  if (!SD.begin(SD_ChipSelectPin)) {  // see if the card is present and can be initialized:
  return;   // don't do anything more if not
```

tactilemap_code §

```
  return;   // don't do anything more if not
  }
 tmrpcm.volume(5);
// tmrpcm.play("1.wav"); //the sound file "1" will play each time the arduino powers up, or is reset
}

void loop(){
 SW1=digitalRead(8);
 SW2=digitalRead(2);
 SW3=digitalRead(7);
 SW4=digitalRead(10);
 SW5=digitalRead(A0);
 SW6=digitalRead(A1);
 SW7=digitalRead(A2);
 SW8=digitalRead(A3);
 SW9=digitalRead(A4);


     if (SW1 == HIGH) { //if SW1 pressed then play file "1.wav"
      tmrpcm.play("1.wav");
     Serial.println("1");
      delay(5000);
    } else if(SW2 == HIGH){ //if SW2 pressed then play file "2.wav"
      tmrpcm.play("2.wav");
      delay(5000);}
    } else if(SW3 == HIGH){ //if SW3 pressed then play file "3.wav"
      tmrpcm.play("3.wav");
      delay(7000);
    } else if(SW4 == HIGH){  //if SW4 pressed then play file "4.wav"
      tmrpcm.play("4.wav");
      delay(7000);
    } else if(SW5 == HIGH){ //if SW2 pressed then play file "5.wav"
      tmrpcm.play("5.wav");
      delay(7000);
    } else if(SW6 == HIGH){ //if SW3 pressed then play file "6.wav"
```

tactilemap_code §

```
sw7=digitalRead(A2);
sw8=digitalRead(A3);
sw9=digitalRead(A4);


    if (SW1 == HIGH) { //if SW1 pressed then play file "1.wav"
     tmrpcm.play("1.wav");
    Serial.println("1");
     delay(5000);
   } else if(SW2 == HIGH){ //if SW2 pressed then play file "2.wav"
     tmrpcm.play("2.wav");
     delay(5000);}
   } else if(SW3 == HIGH){ //if SW3 pressed then play file "3.wav"
     tmrpcm.play("3.wav");
     delay(7000);
   } else if(SW4 == HIGH){  //if SW4 pressed then play file "4.wav"
     tmrpcm.play("4.wav");
     delay(7000);
   } else if(SW5 == HIGH){ //if SW2 pressed then play file "5.wav"
     tmrpcm.play("5.wav");
     delay(7000);
   } else if(SW6 == HIGH){ //if SW3 pressed then play file "6.wav"
     tmrpcm.play("6.wav");
     delay(7000);
   } else if(SW7 == HIGH){  //if SW4 pressed then play file "7.wav"
     tmrpcm.play("7.wav");
     delay(7000);
     } else if(SW8 == HIGH){ //if SW3 pressed then play file "8.wav"
     tmrpcm.play("8.wav");
     delay(7000);
   } else if(SW9 == HIGH){  //if SW4 pressed then play file "9.wav"
     tmrpcm.play("9.wav");
     delay(7000);
   }
}
```

```
Sketch uses 12054 bytes (37%) of program storage space. Maximum is 32256 bytes.
Global variables use 1070 bytes (52%) of dynamic memory, leaving 978 bytes for local variables. Maximum is 2048
```

<u>Appendices</u>

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