

# **GNG2101 Final Report**

## **Tactile Mapping of the First Floor of The Public Health Agency located at 785 Carling Avenue, Ottawa, ON, Canada**

Submitted by

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## **Abstract**

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Navigating the world can be a great challenge for those who are visually impaired. It is the reason why many societies implement technologies such as tactile paving, braille signs and tactile mapping within their cities to make such a task much more practical. Over the course of three months, we have worked to develop our own technology that would aid visually impaired employees and visitors navigate the first floor of the Public Health Agency of Canada located at 785 Carling Ave. Our client Graham Sparo, an accessibility advisor to both the Parliamentary Precinct Accessibility Advisory Committee and the Centre Block Rehabilitation Project, was the one to oversee this project. With the knowledge, materials and machinery at our disposal, we developed a tactile map of the first floor of the building to give users directions to all the essential spaces within it. We digitally modelled our map keeping the design simple with a concise layout and legend. We then transferred our model into Inkscape, a professional graphics software that we used to laser cut the map into an acrylic board. To finalize our project, we added audio to give our users bilingual indications and a mount to showcase our product and make it easier to explore. Overall, we were able to come up with an original design that satisfied the core requirements of our users.

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# **1 Introduction**

## **1.1 The Problem**

Being a visually impaired employee or visitor at the Public Health Agency complicates wayfinding within the building. Without clear indications on how to get around the already confusing building, an employee or visitor may get lost or even get hurt while trying to find their way. With the help of a tactile map, visually impaired individuals would have a more efficient and effective way of getting around. Facilitating wayfinding for visually impaired employees would offer them a more optimal work environment in which they can better perform. Making the building more accessible will also give visually impaired employees a sense of inclusivity within their workplace.

## **1.2 User Requirements**

In order to meet our users' needs, we were required to create a tactile map that respected certain design criteria. The map had to be simple and easy to read while identifying essential elements such as important room numbers, doors, emergency exits, a critical path, etc. It was also important that our map be durable and that it incorporated an audio component that would give bilingual indications.

## **1.3 Our Solution: Key Product Specs**

The product we developed was able to meet these fundamental requirements. From the floorplan, we eliminated all elements that were uninformative or unnecessary and reduced it to a simplified layout. We avoided braille as to not clutter the map unnecessarily, keeping in mind that only 4% of visually impaired individuals can read it. We instead opted for tactile text to identify the main rooms and washrooms. We used different textures to identify a few other components (). Finally, the audio buttons integrated into the legend and main rooms tied the whole project together. When a button is pressed within the legend, there is an explanation as to what the texture in the



legend represents (in both French and English). There are also audio buttons in the 4 main rooms and washrooms which indicate what they are. Moreover, the materials used to build the map are of high quality yet very affordable making it possible for us to offer a quality product without breaking our customers bank. All in all, our tactile map is quite the package and is sure to be of at least *some* use to any visually impaired individual visiting the first floor of the Public Health Agency.

## 2 Engineering Design Process

### 2.1 General Overview

We chose to use the design thinking approach for this project since it is the best method for addressing our users and their needs. This design process focuses largely on empathy and rapid iterative prototyping. Empathy was a key attribute during the entire progression of our product development. Having not experienced what it is like to be visually impaired, it was important that we, above all, understand the state of the user and their specific challenges and needs. It helped us focus our design and make sure we were solving the problem correctly. By trying to understand the user, it made it easier for us to design something that would appeal and be useful to *them* and not something that *we* thought would be useful. This is key since the main goal of product development is consumer satisfaction. It was also useful that this design process relied heavily on producing many prototypes. This allowed us to get a lot of necessary feedback that steered our design in the right direction. Overall, this design process was excellent and allowed us to obtain our objective of creating a product that worked properly and efficiently all while making an impact on the life of the user.

### 2.2 Segmented Overview

**Empathy:** We met with our client and visually impaired users to discuss their lives and the challenges they face in an effort to understand their needs.

**Define:** We established a problem statement that focuses on the goal of our product development.

**Ideate:** We generated a series of concepts and evaluated them using a matrix before finalizing our concept choice.

**Prototype:** We created three different prototypes before finalizing our product.

Test: Our first prototype was used to test the dimensioning and the visualization of our map. We had visually impaired users feel and use our second medium-fidelity prototype. Now we have sent our final product back to our client and are waiting for feedback.

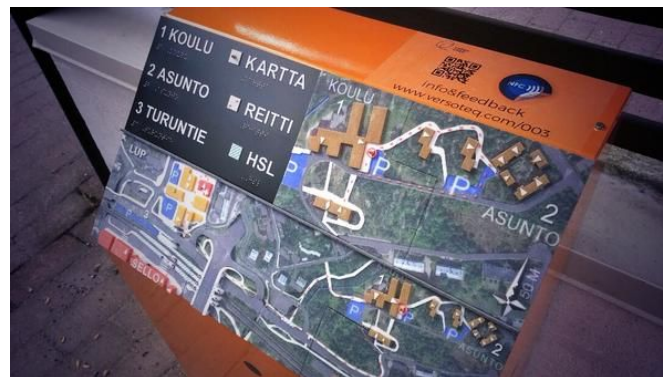
### 3 Need Identification and Product Specification Process

#### 3.1 Problem Statement

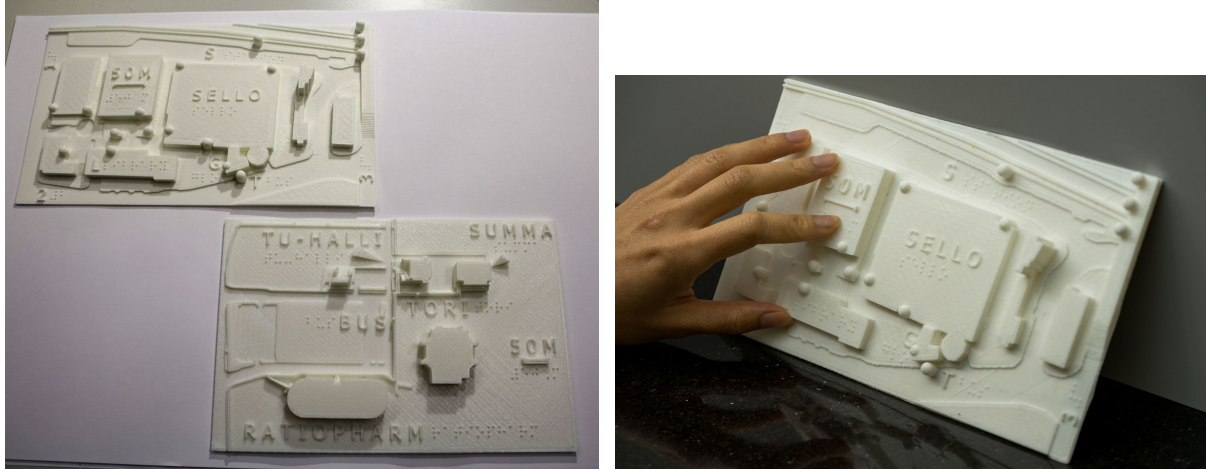
Our team has taken on the task of creating a tactile map to help visually impaired employees and visitors who sometimes have trouble navigating the first floor of 785 Carling Avenue.

#### 3.2 Benchmarking

Benchmark 1: Stationary Tactile map at Keskuspuisto Vocational College



Benchmark 2: Portable Tactile Map of the Tapiola Sports Park and Sello Shopping Center surrounding the GLO Hotel for the IBSA Goalball World Championships 2014



Benchmark 3: Stationary TactMap at BrailleTech 2016



### 3.3 List of Metrics with their Respective Units

- Weight (kg)
- Map size (inches)
- Map thickness (cm)
- Tactile lettering size (mm)
- Scale accuracy (mm)

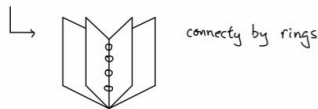
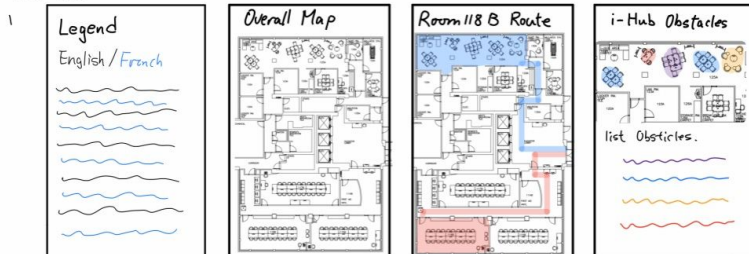
### 3.4 Target Specifications

	Design Specifications	Relation (=, < or >)	Value	Units
No.	Functional Requirements			
1.	Weight	=<	5	kg
2.	Dimension	=<	50 x 60	cm
3.	Thickness	=<	3	cm
5.	Writing size	=<	15	mm
6.	Map scale accuracy (margin of error)	=<	2	mm

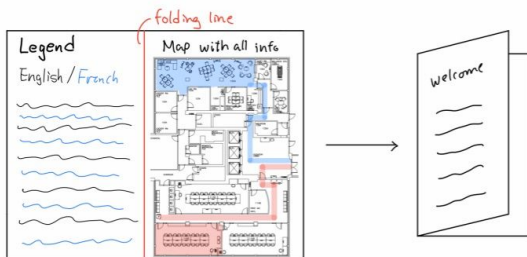
## 4 Conceptual Designs

### Generated Concepts after Initial Brainstorming

Portable



2) Pressed Paper using a mold.

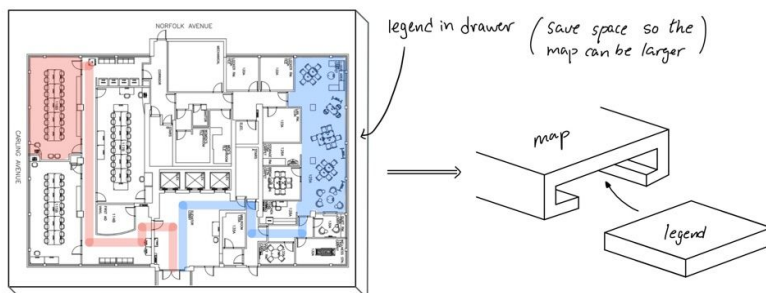


### Portable Design Concepts:

#1: Booklet-style map, 3D printed pages linked together with large rings

#2: Pamphlet-style map made with pressed (textured) paper.

Stationary



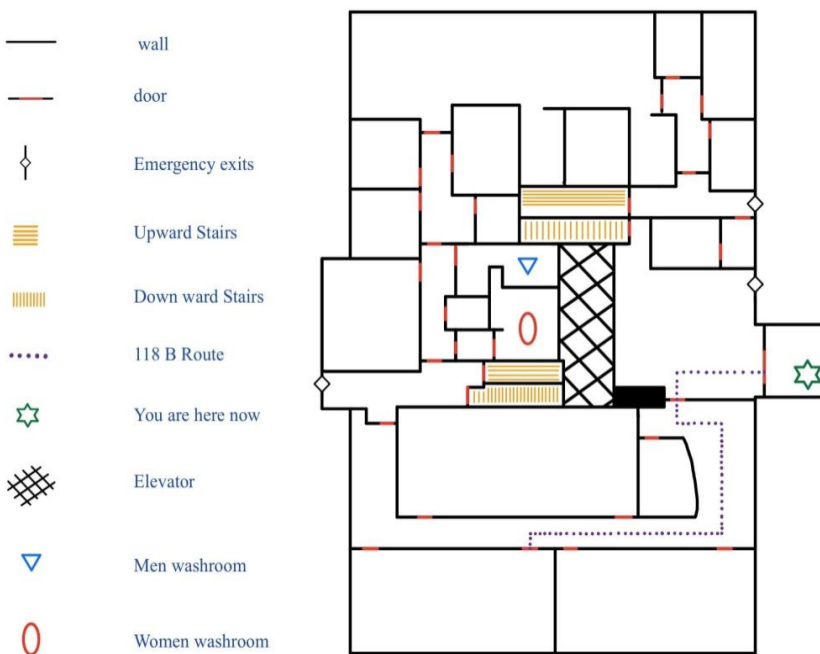
### Stationary Design Concepts:

#1: Regular tactile map with a twist: there is a slot within the map and it contains the legend (compact design).

#2: Regular, traditional tactile map with a legend on one side.

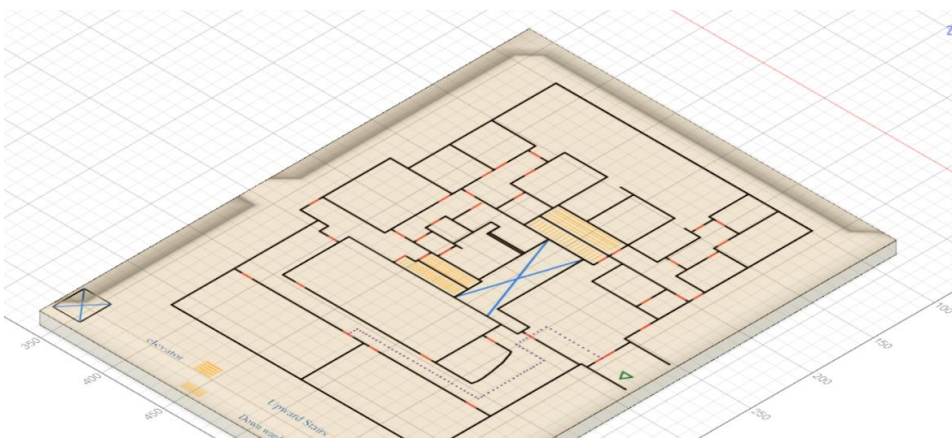
At first, we had decided to develop the first stationery design. However, after consulting with our client we settled on the last concept since he encouraged us to be as simplistic as possible.

### Initial Map Layout

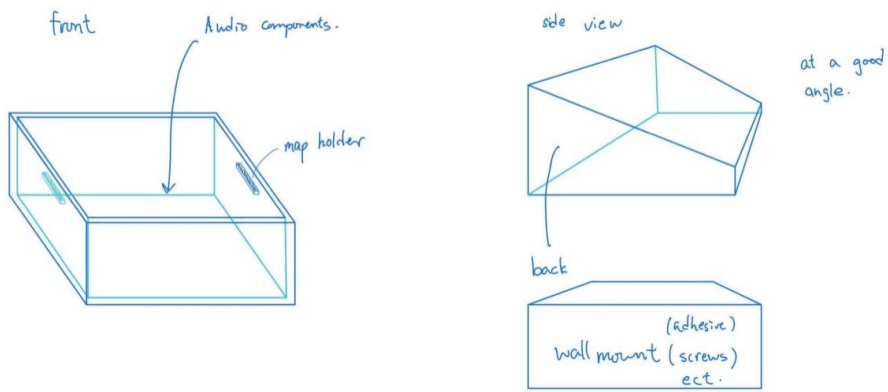


After our second client meeting, this was the initial map layout we designed. We had initially planned on 3D printing our map and did not include any audio component.

### 3D Model of a Slight Variation of our Initial Map Layout



### Slanted Mount Design (for upholding and displaying the map)

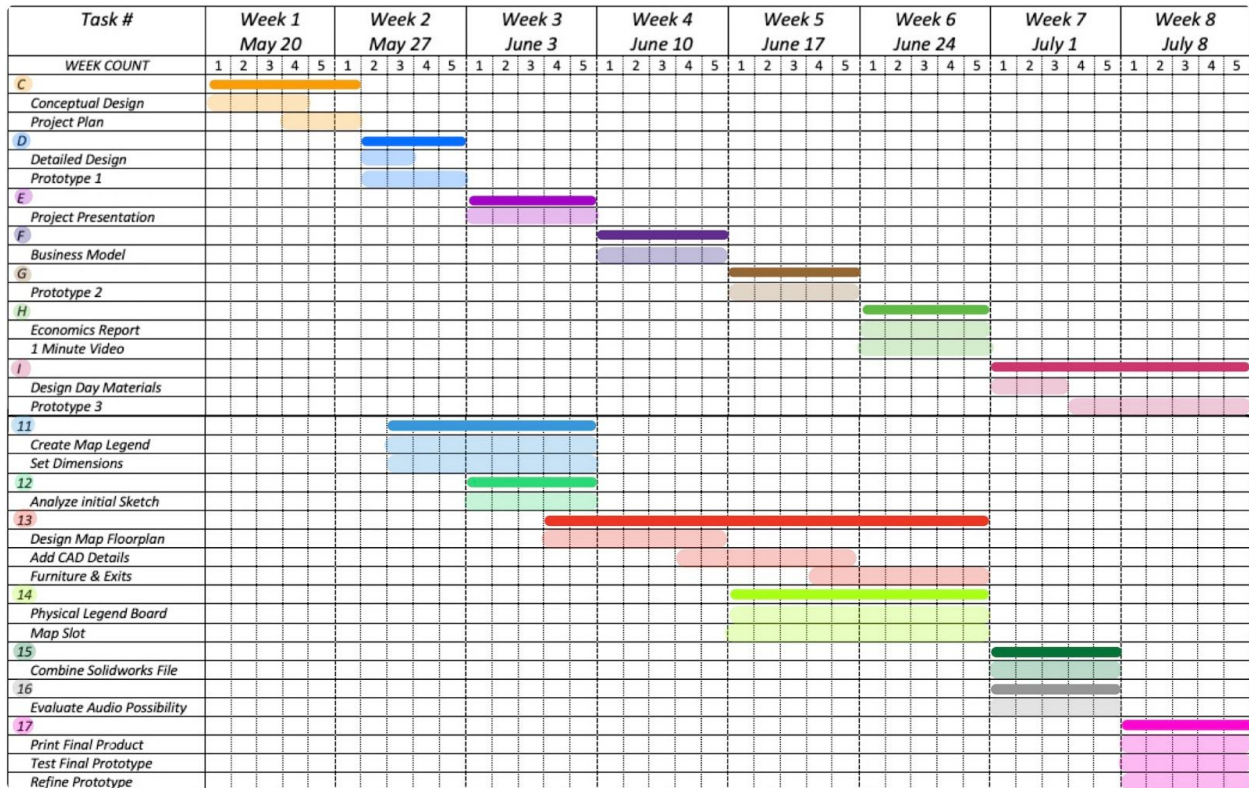


## 5 Project Planning and Feasibility Study

### 5.1 Project Planning

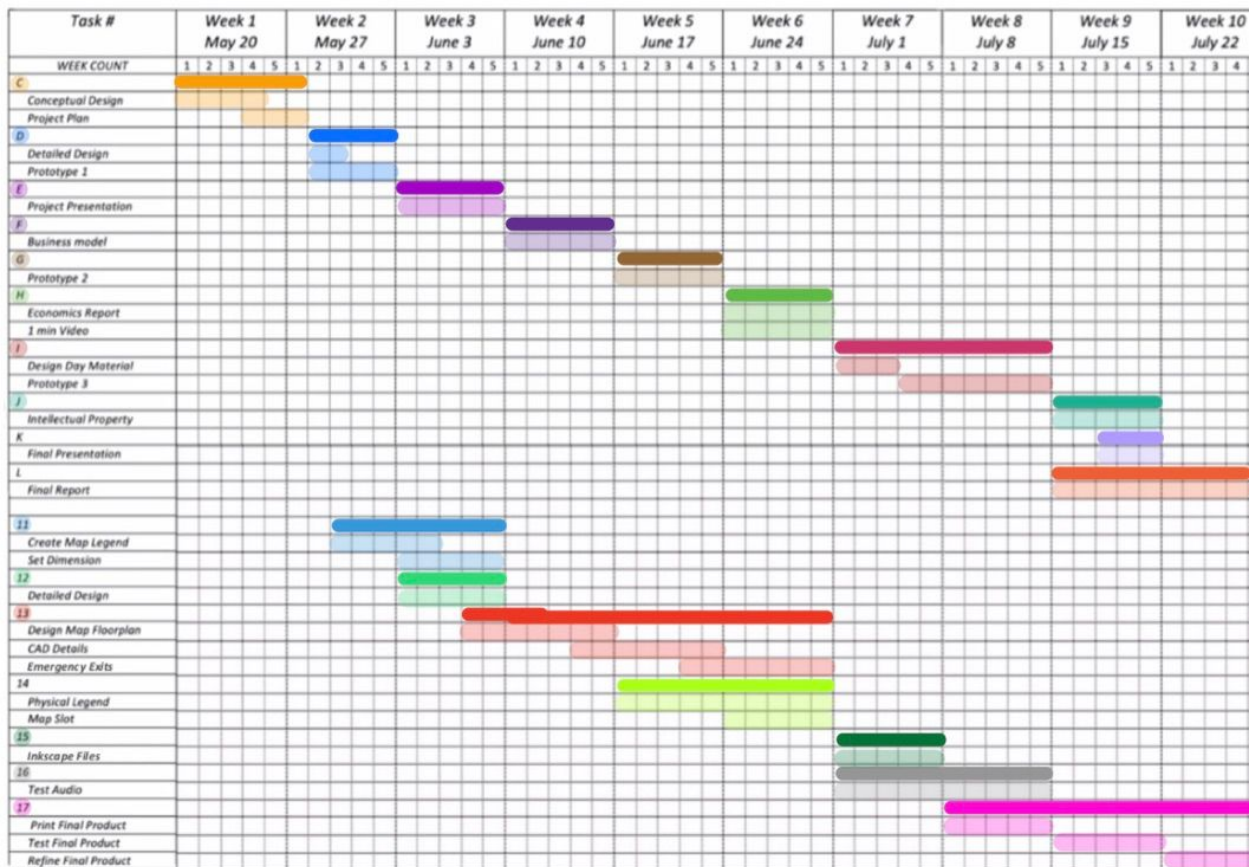
Our initial project plan revolved around developing the map with the legend slot. That being said, once we shifted towards the more traditional map, we had to update most of it. The only elements that remained the same in both plans were the deliverable due dates.

#### Initial Project Plan





## Updated Project Plan



## 5.2 Feasibility Study

**Technical:** One of our team members is very agile in using the Solidworks software. The rest of our team has had basic training in Solidworks during the GNG1103 course last semester. However, using Solidworks is a skill most of our team still needs to work on and develop. Our team also has experience using other CAD software such as AutoCAD and Inkscape. This may help us adapt to using Solidworks much easier and with the support of our agile team member,

we will be able to produce good results. All of our team members are trained in 3D printing and know how to operate the 3D printers available to us at STEM. Some members have had previous training using the laser cutter. All the software necessary to design and print our map is free to us and accessible.

**Economic:** A 1kg roll of 3D printer filament can range anywhere between \$20 and \$100+ dollars depending on the type of material, the quality, and the manufacturer. Our map will not weigh more than 5 kg so we could build a 5 kg map with a \$20/kg filament. However, if we are able to stick to the 2-3 kg range, we would be able to get better quality filament for a higher price per kilogram. Generally speaking, funding our project is feasible.

\*We had assumed that we would be 3D printing our map.

**Legal:** There are no legal issues related to releasing our solution to the public.

**Operational:** Our group is able to perform well on tasks in a timely manner. The organization should not be an issue and will be highly prioritized in order to remain effective.

**Scheduling:** Deadlines and due dates have been compiled in a planning table and will be respected.

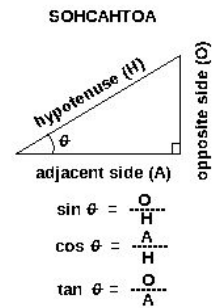
## 6 Analysis

### 6.1 Formulas

Tangent of angle  $x = \frac{\text{opposite side}}{\text{adjacent side}}$

Cosine of angle  $x = \frac{\text{adjacent side}}{\text{hypotenuse}}$

Inches to millimeters: 1 inch = 25.4 millimeters

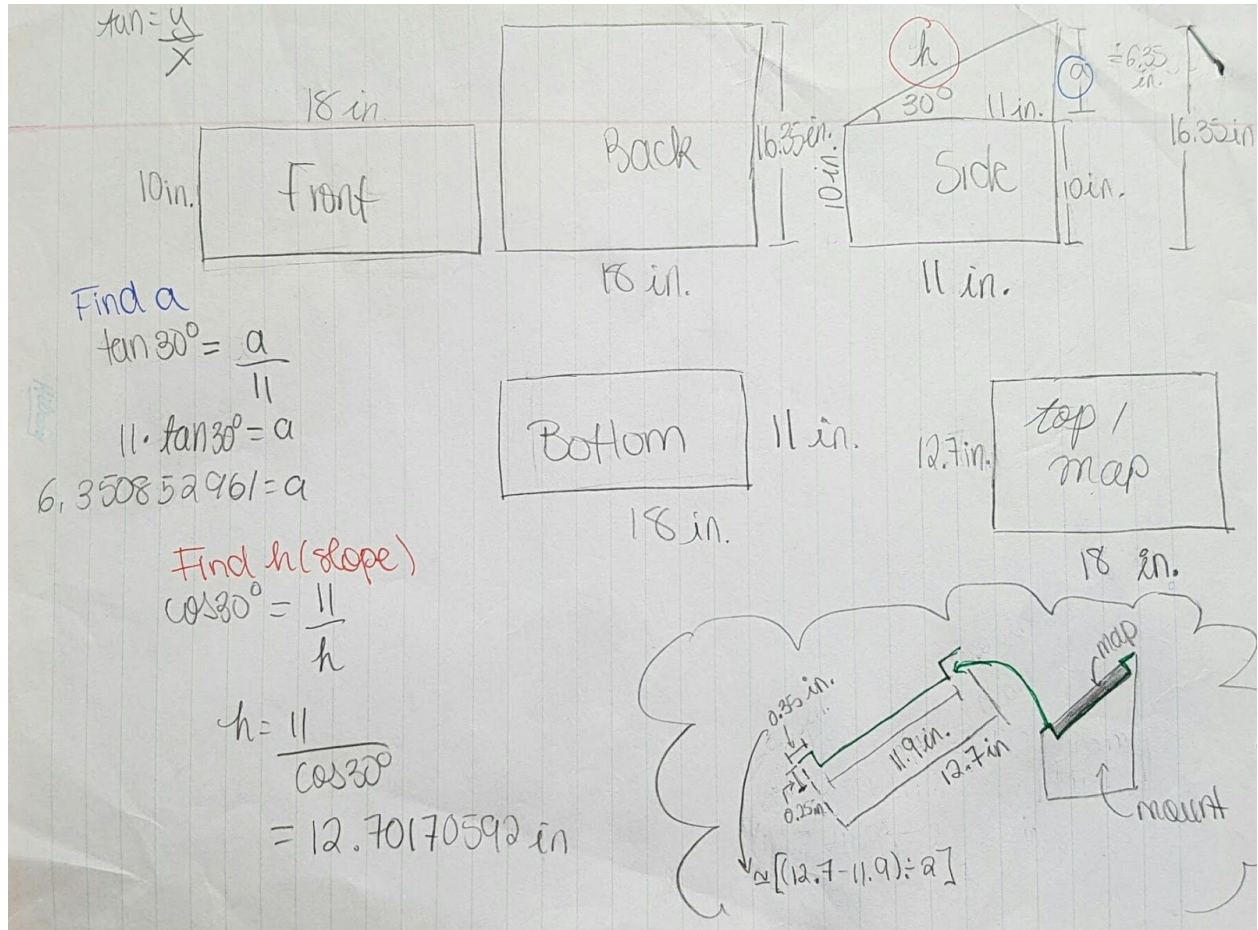


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### 6.2 Calculations

#### Mount Dimensions

<sup>1</sup> SOCAHTOA image taken from <https://study.com/academy/answer/how-do-you-use-sohcahtoa-on-your-calculator.html>



Our previous measurements for the mount were in inches and had to be converted to millimetres in order to be able to use the boxes.py box generator. This software generated the laser-cutter ready parts for the assembly of our mount.

## UNEVENHEIGHTBOX

Box with different height in each corner

### ► Settings for Finger Joints

#### ▼ UnevenHeightBox Settings

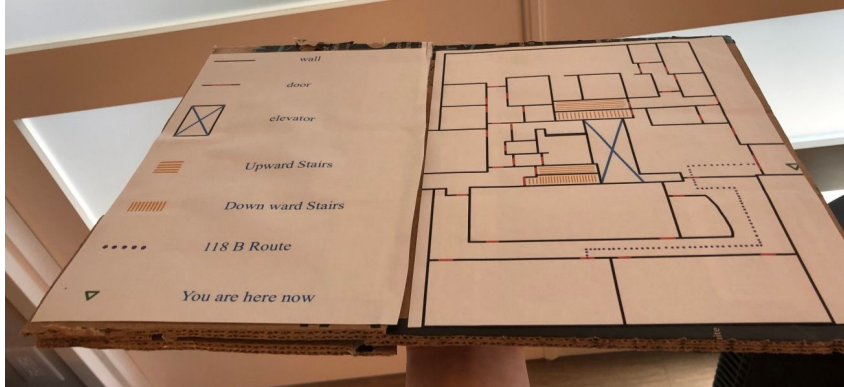
bottom_edge	F Finger Joint (opposing side) ▼	edge type for bottom edge
x	457.2	inner width in mm (unless outside selected)
y	279.4	inner depth in mm (unless outside selected)
outside	<input checked="" type="checkbox"/>	treat sizes as outside measurements that include the walls
height0	254	height of the front left corner in mm
height1	254	height of the front right corner in mm
height2	415.3	height of the right back corner in mm
height3	415.3	height of the left back corner in mm
lid	<input type="checkbox"/>	add a lid (works best with high corners opposing each other)

## 6.3 Data Collection

Only 4% of visually impaired people can read braille (information provided to us by our client).

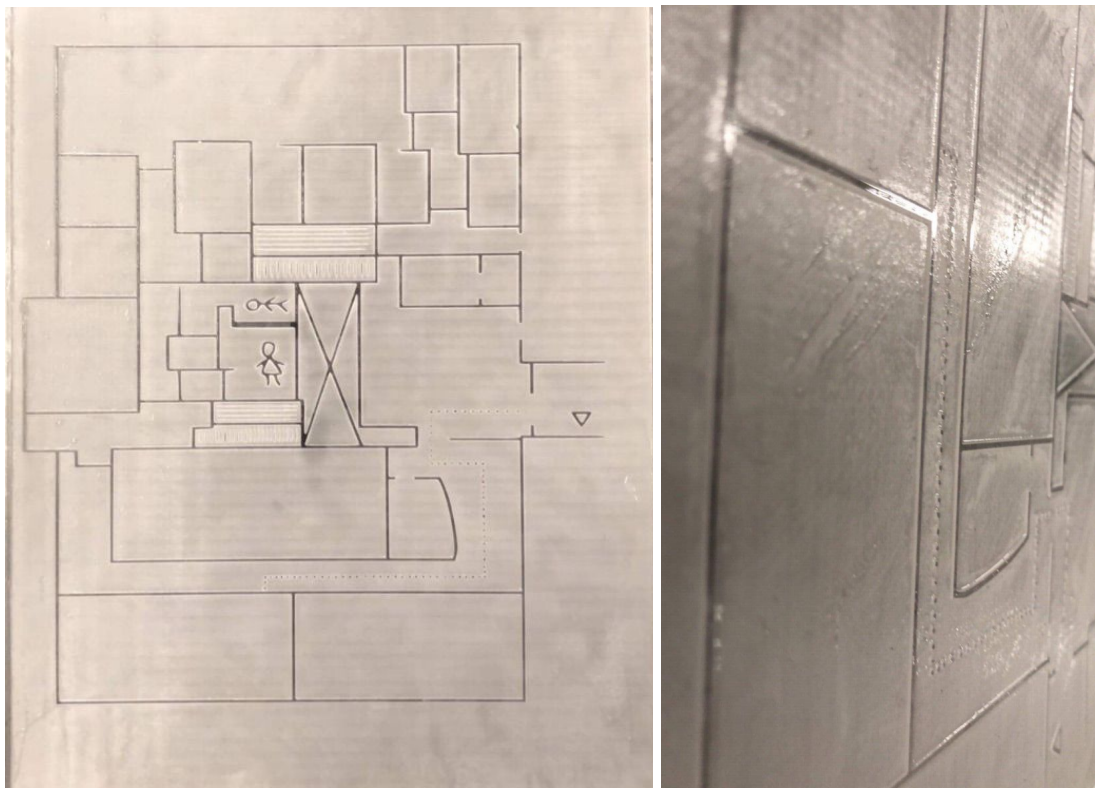
## 7 Prototyping, Testing and Customer Validation

### Prototype 1



The purpose of this was to test the size of the map and how the components fit together onto it.

## Prototype 2



\*The dotted lines represent the critical path that can easily be followed by the user. It serves as a primary way of finding important rooms of the first floor.

The purpose of this prototype was to test the depth of cut needed for the user to be able to clearly navigate the map. From this prototype, we learnt that in order for the elements of the map to be

distinguishable, we need to raster the acrylic board at least twice. However, rastering the acrylic board three times is optimal as it gives the best results.

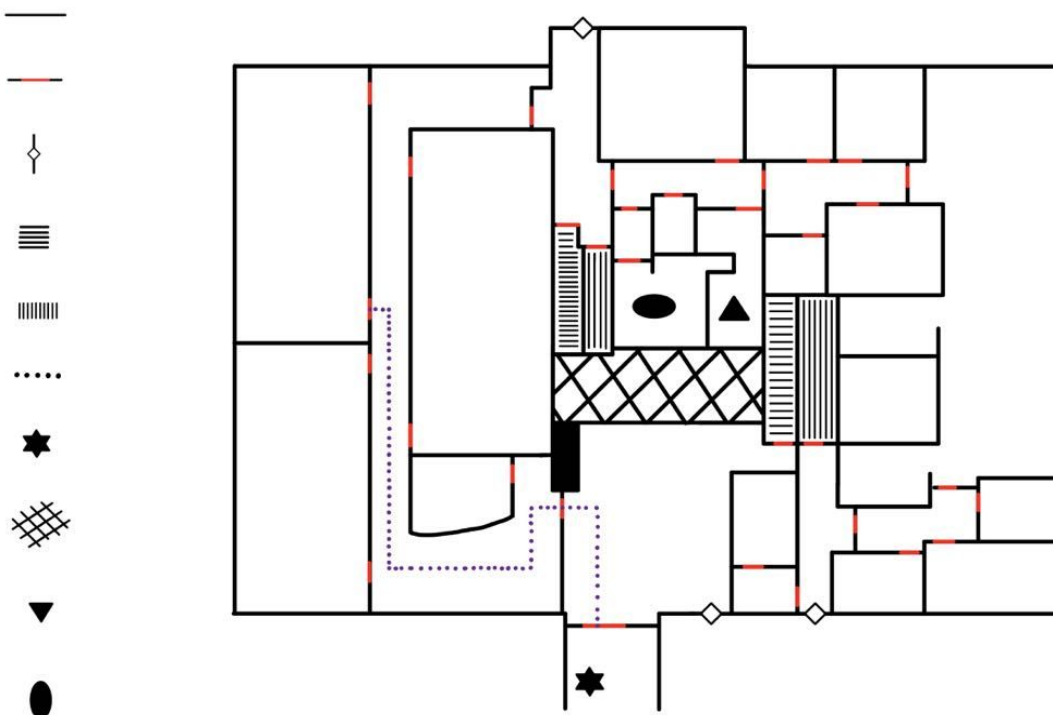
## **7.2 Testing and Customer Validation**

As we progressed in our design process, we made sure of getting constant validation from our client. We had our second prototype sent to Jeff, a visually impaired user, for testing. We were told that the feel of the acrylic and the textures lasered on to it was good especially the critical dotted path. As a suggestion, we were asked to keep the same material but to add colour contrast to it. After our second prototype, we implemented that change and made sure to get continuous feedback from our client whenever we decided to add new features or modify existing ones. Before laser cutting our final map, our client paid us a visit where he gave us a set of new modifications to be made to optimize our final design. We simplified the legend; added the names of important rooms in tactile lettering accompanied by audio buttons; added a title to the map in tactile lettering and, finally; modified the critical dotted path so that it would go all the way around the building. In sum, on-going feedback from our client and user gave us the necessary validation that our product was heading in the right direction.

## **8 Final Solution**

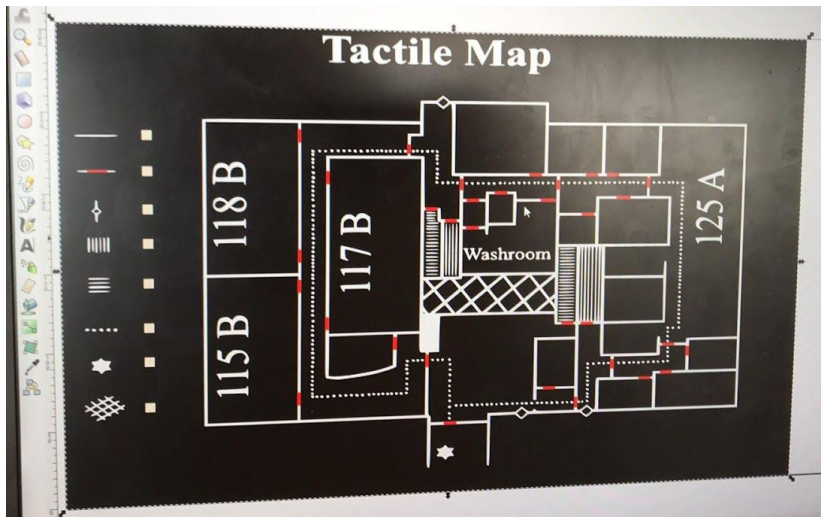
Our final product consists of three main parts. The first is the tactile map itself. It is an  $18 \times 11.9$  inch black acrylic board that was painted over in white then rastered twice by a laser cutter to outline the floorplan (map layout) in white on the black surface. The second is the mount. It is made of 5 pieces of laser cut medium-density fibreboards that are linked together by their finger joints to make a box. Lastly, we have the audio. The audio component of our project mainly works with a Raspberry Pi 3B+ chipboard. This electronic circuit is a micro-computer and can be programmed to achieve diverse tasks. In our case, we developed a program that plays a specific sound file that we recorded whenever it detects a voltage input on a specific pin existing on the board. The voltage is received at a pin whenever we press a small tactile switch button on the map. That button has a permanent 5V input as well as an output that leads to the pin in question while being brought to ground by a pull-down resistor at the same time. The push of the button allows the electrons to flow and supply power to the pin, an input which will be detected by the computer resulting in the playback of the designed sound file. The script that we designed was also configured to figure into the startup executable files of the micro-computer in order to always have the program running at all times.

### Final Map Layout





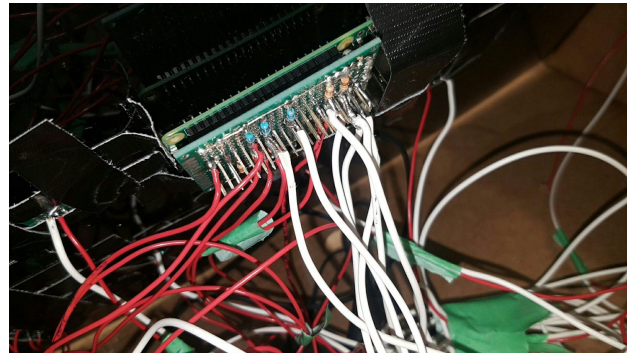
**Inkscape file of the layout (includes slots for audio buttons next to the legend)**



**Physical Finished Product**



**Audio Component**



### **8.1 Final Testing Results**

We sent our final product to our user and he made the suggestion of adding an audio button that would give a general overview of the layout of the map. After implementing this final change, our product was finally complete.










## 9 Business model

### 9.1 Chosen Model and Business Operation

The brick and mortar business model seem to be the most suitable for commercializing our tactile map. A brick and mortar business is a traditional business that serves its customers within a physical location. Examples of brick and mortar businesses include grocery stores, banks and retail shops. Crucially, since our targeted users are visually impaired, they must be able to come into contact with our map in order to actually understand, interact with and test it before deeming it worthy of being purchased.

Our business will operate similarly to the way an engineering firm operates. We will meet with our customer/client at a physical location and discuss the design project (the map itself, materials, textures, cost, etc.). After gathering the required information, we will build the map at our location. Once the map has been produced, our customers will have the option of coming in store to pick up the product and pay for it. Otherwise, the customer would have paid for it in advance and we would have it delivered to them.

### 9.2 Business Model Canvas

<p><b>Key Partners</b> </p> <ul style="list-style-type: none"> <li>• Graham Spero, accessibility advisor</li> <li>• The Parliamentary Precinct Accessibility Advisor Committee</li> <li>• University of Ottawa</li> <li>• The Public Health Agency</li> </ul>	<p><b>Key Activities</b> </p> <ul style="list-style-type: none"> <li>• Product Development &amp; Management</li> <li>• Clients Meetings</li> <li>• Team Meetings</li> <li>• Prototypes Building</li> </ul>	<p><b>Value Proposition</b> </p> <ul style="list-style-type: none"> <li>• Product is custom built</li> <li>• Low price</li> <li>• High quality</li> <li>• Offers diverse map styles (portable/ stationary)</li> </ul>	<p><b>Customer Relationships</b> </p> <ul style="list-style-type: none"> <li>• Email</li> <li>• Customer Service</li> <li>• Telephone</li> <li>• Online web page</li> </ul>	<p><b>Customer Segments</b> </p> <ul style="list-style-type: none"> <li>• Companies / Organizations looking to introduce accessibility measures for visually impaired persons.</li> </ul>	
<p><b>Key Resources</b> </p> <ul style="list-style-type: none"> <li>• University of Ottawa's MakerSpace</li> </ul>		<p><b>Channels</b> </p> <ul style="list-style-type: none"> <li>• Sold at a physical location</li> <li>• Delivered if custom built</li> </ul>		<p><b>Cost Structure</b> </p> <ul style="list-style-type: none"> <li>• Fixed cost such as 3D printing filament</li> <li>• Product development</li> <li>• Running Cost (Rent, Hydro, etc)</li> <li>• Salaries</li> </ul>	<p><b>Revenue Streams</b> </p> <ul style="list-style-type: none"> <li>• Map Sales</li> <li>• Consultation fees</li> <li>• Map Design fees</li> <li>• Tactile Map parts (audio components)</li> </ul>

## 10 Economic Analysis

### 10.1 Business Costs

Cost #	Description	Cost Classification
1	Marketing	Fixed Indirect
2	Production Equipment (machinery)	Fixed Direct
3	Production Materials	Material, Variable Direct
4	Electricity	Semi-variable
5	Salary	Labour, Fixed Direct
6	Consultation Office Furniture and Equipment	Material, Fixed Direct
7	Rent	Fixed Indirect
8	Financial Cost (debt)	Fixed Indirect
9	Overhead	Fixed Indirect
10	Depreciation	Fixed Indirect
11	Tax	Taxation Cost

### 10.2 3-year Income Statement

Tactile Co. is a Canadian company that specializes in the design and manufacturing of tactile maps. Tactile Co. plans to produce and sell 1510 tactile maps at \$400 per unit in its third year of operation. It also plans to spend \$25,000 for marketing campaigns, \$40,000 for production equipment, \$170,000 for production materials, \$85,000 for electricity, \$125,000 for salaries, \$60,00 for the consultation office furniture and equipment. Finally, \$20,000 will go towards paying overhead costs, \$25,000 for rent and \$10,000 for depreciation cost. Tactile Co. also has a debt of \$100,000 at an annual simple interest rate of 5% and a 25% income tax rate.

<b>Position #</b>	<b>Description</b>	<b>End of Third Year (\$)</b>
1	<b>Revenue</b>	
1.1	Sales (1510 x \$400 )	\$604,000
2	<b>Operating Expenses</b>	
2.1	Marketing	\$25,000
2.2	Production Equipment	\$40,000
2.3	Production Materials	\$170,000
2.4	Electricity	\$85,000
2.5	Salary	\$125,000
2.6	Consultation Office Furniture and Equipment	\$60,000
2.7	Rent	\$25,000
2.8	Overheard	\$20,000
2.9	Depreciation	\$10,000
2.10	Total Operating Expenses	\$560,000
3	<b>Operating Income (#1.1- #2.10)</b>	<b>\$44,000</b>
4	Interest Expenses (\$100,000 x 0.05)	\$5000
5	<b>EBT (Earnings Before Taxes)</b>	<b>\$39,000</b>
6	Income Taxes (#5 x 0.25)	\$9,750

7	<b>Net Income (#5 - #6)</b>	<b>\$29,250</b>
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### 10.3 NPV Analysis

The break-even point is the moment at which the revenue is able to cover all operating expenses and Tactile Co. begins making profit. In such case:

units sold x price per unit = operating expenses

$$\text{units sold} \times \$400 = \$560,000$$

$$\text{units sold} = 1,400$$

In summary, Tactile Co. must sell 1,400 in order to break even.

### 10.4 Assumptions

While developing this economics report, we assumed that our company would be able to reach a large clientele that includes countries outside of Canada. We would be fulfilling bulk orders as well (i.e. in the case of large events such as sports events for people with visual impairments).

We wanted to have a bigger marketing budget as we presumed that tactile maps are not a commonly used product and would need to be

marketed well in order to reach out to our desired consumers. These first three factors would help increase sales. Moreover, each map would only require a small team of people from the design phase to building the finished product which helps save money on salaries (labour cost).

Finally, the materials used to build our maps would be inexpensive (acrylic, plastic, etc.) and provided by Canadian companies making our them more affordable.

## **11 Conclusions and Recommendations for Future Work**

Working on this project gave us the opportunity to expand and apply our knowledge of project management and product development. We learned to have positive and fruitful interactions with our client and with potential users which facilitated the needs identification process. We established design criteria and generated concepts as a team then used a decision matrix as well as our client feedback to make a concept selection. We familiarized ourselves with new machinery, hardware and software to develop two prototypes and, finally, our final product. It was a learning process for us that taught us many new skills. Working as a team taught us to understand the strengths and weaknesses of each member and to accept disbalance within a team. Instead of seeing it as a weakness, we were encouraged to utilize everyone's strengths to optimize the quality of work we put out as a team. We've also learned that it takes constant communication and feedback from our client to ensure our product design progresses in the right direction. As for future work, there are a few key elements we could expand on to perfect our project. After the completion of our final product, we noticed that applying white paint to the acrylic board before rastering it took away from the smoothness and aesthetic of the surface. To improve this, we would explore different methods of changing the colour of the material. Moreover, we were suggested to build more than a single map so that they could be displayed in different places around the floor of the building. We would definitely consider this if we were to turn this into a large scale project. All in all, we are proud of our results and are sure that the valuable takeaways we have from this project will serve us in our future project endeavours.

## **12 Bibliography**

[SOHCAHTOA]. Retrieved from

<https://study.com/academy/answer/how-do-you-use-sohcahtoa-on-your-calculator.html>

## APPENDICES

### APPENDIX I: User Manual

Our tactile map is extremely simple to use. Here are the steps to follow:

- 1) Make sure that the power supply for the map is plugged into a power output.
- 2) Allow at least 2 minutes for the maps electronic software to boot up.
- 3) The maps is now ready to be used. On the left portion you can find the legend whilst the layout of the building takes the rest of the map.
- 4) The button in the top left corner is the instruction button. It orally gives the layout of the map.
- 5) The rest of the buttons are ready to be used and give specific information depending on their location on the map.
- 6) Feel your way around the map and orient yourself using the diversified guides.

#### Cleaning Instructions

Here are the steps to maintaining and cleaning the map:

- 1) Make sure that the power supply for the map is unplugged
- 2) Wait a few seconds to allow electron flow to come to a stop
- 3) To prevent damaging the paint and acrylic, soak a wool cloth into water and gently rub the surface of the map in a circular motion.
  - Only use water, not any other chemical product.
- 4) Do not dry the surface with any cloth. Either let dry to ambient air or use a heat device to dry the surface without any contact, but by convection of air.

#### Troubleshooting

Here are basic troubleshooting tests to help you solve audio issues:

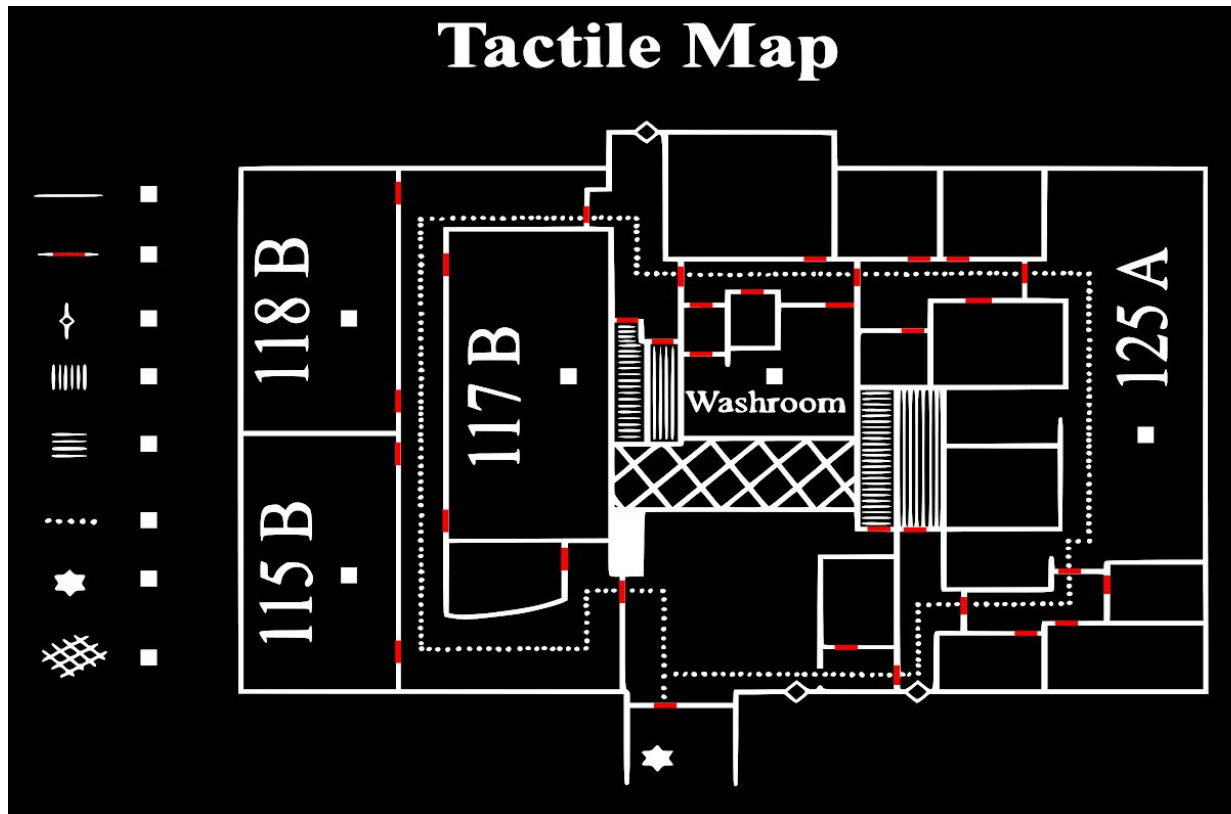
- 1) Make sure that the power supply is well plugged in into the powersource as well as into the electronic circuit micro-usb entry.



- 2) Allow at least 2 minute for the electronic circuits to be ready to be used.
- 3) Try to change the speaker or the audio jack cable linking the speaker to the circuit board.
- 4) If none of these steps solved your issue, contact administration.

## APPENDIX II: Design Files

### SVG Map File



### Audio Files and Code File for Programming the Arduino to Play Them

Door	WAV File	226 KB	No	423 KB	47%	2019-07-13 1:02 AM
DownwardStaircase	WAV File	433 KB	No	657 KB	35%	2019-07-13 12:51 AM
Elevator	WAV File	334 KB	No	501 KB	34%	2019-07-13 12:55 AM
EmergencyExit	WAV File	425 KB	No	659 KB	36%	2019-07-13 12:49 AM
Layout	WAV File	2,451 KB	No	3,759 KB	35%	2019-07-21 12:54 PM
Pathway	WAV File	449 KB	No	687 KB	35%	2019-07-13 12:54 AM
Position	WAV File	489 KB	No	767 KB	37%	2019-07-13 12:55 AM
Room115B	WAV File	470 KB	No	733 KB	36%	2019-07-13 12:56 AM
Room117B	WAV File	466 KB	No	691 KB	33%	2019-07-13 12:57 AM
Room118B	WAV File	425 KB	No	636 KB	34%	2019-07-13 12:56 AM
Room125A	WAV File	478 KB	No	753 KB	37%	2019-07-13 12:59 AM
Sb.py	PY File	1 KB	No	4 KB	83%	2019-07-24 1:17 AM
UpwardStaircase	WAV File	398 KB	No	607 KB	35%	2019-07-13 12:51 AM
Wall	WAV File	241 KB	No	415 KB	42%	2019-07-13 12:47 AM
Washroom	WAV File	268 KB	No	457 KB	42%	2019-07-13 12:58 AM

These files are available on our MakerRepo at the following link:

<https://makerepo.com/murivx/2101-tactile-map>.