**GNG 1103 [F]**

**Engineering Design**

Course Professor: **Rubina Lakhani**

# Deliverable D - Conceptual Design

Prepared by Group: # 4

Team Members:


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## Introduction

This deliverable focuses on the ideation phase of the design process, which involves the concept generation from each team member and then an exchange and integration of ideas. Everyone will complete the design of the sidewalk independently and explain the product reasonably from the inside out during a team meeting. Then everyone will combine the advantages of each design concept and come up with three designs. Then, finally using a selection matrix and a group discussion a final concept to move forward with will be chosen.

### 1.0 Subsystems in Design

*External:*

The external aspect of our design revolves around the modularity and connectivity of the design. Specifically, the goal is to have a network of panels, interconnected in both lateral directions, while all being powered by the same source. Thus, our conceptual designs must include methods by which the panels can be moved, compacted for storage, attached to one another, and share power. The outer surface of the panels must also provide adequate traction for pedestrians. It must also provide sufficient water drainage such that water from melted snow and ice does not accumulate on the surface of the panels, reducing traction and potentially the function of the panels.

*Internal:*

The internal subsystem of the design encompasses the heating method, as well as all necessary sensors and electronics that will be used to improve the functionality and reduce the power requirements of the design. This includes the choice of heating method (for example, wire filament, radiation from heating water, etc.), and the implementation of proper heat-conductive materials such that the low-grade heat is able to effectively reach the outer surface of the walkway panel. The use of various sensors, in conjunction with an Arduino Uno board, will also be taken into consideration in this subsystem, since the heating function of the panels is not intended to be operating at all times.

*Maintenance:*

The maintenance subsystem is meant to exclusively illustrate how the internal components can be accessed for repairs. Since the longevity of a product is highly dependent on how well it can be maintained, it is necessary to include features which allow for the ease of access to key features of the panels, such as the power wiring, heating fixtures, sensors, Arduino board, etc. If any of these features become inaccessible, the cost of repairs is instantly increased, and the likelihood the panel will need to be removed entirely is significantly higher. Since the

product is intended to have a usage life of 10+ years, it is of the utmost importance that the maintenance aspect of the design is simple and effective.

## 2.0 Design 1

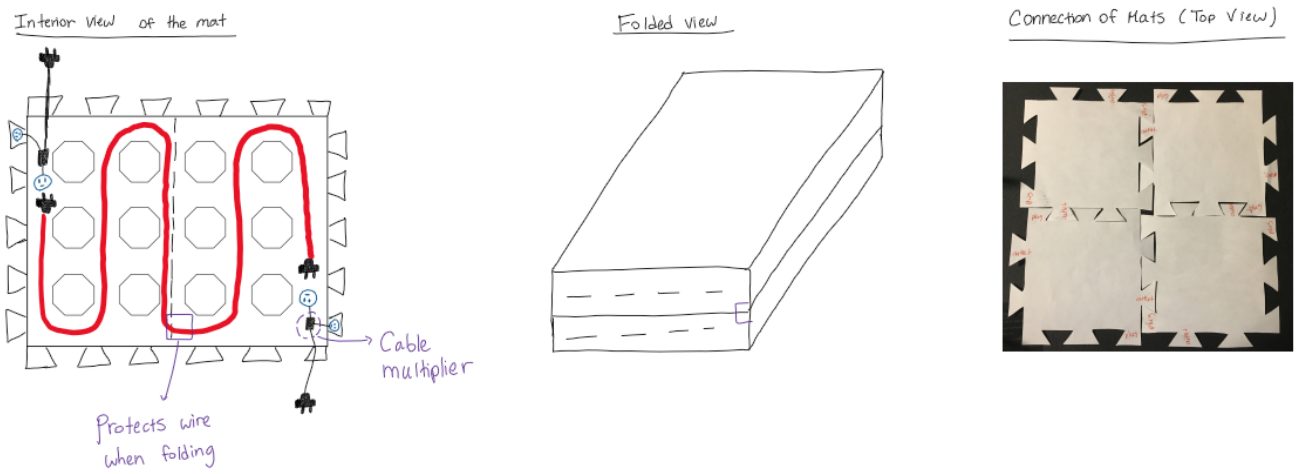



Figure 1. Initial sketches of Design 1

This design uses an electric heat cable as it's heating element for the mat. This wire would then be wrapped around studs, so that the wires are held apart to prevent them from touching and burning each other. The studs will also tightly squeeze the wire in place while also still being a temporary hold, so that if the wire ever needs to be replaced, the maintenance crew can just tug on the wire to remove it from the grip of the stud.

Additionally the studs will provide support to the top layer of thermoplastic that will cover the internal workings of the mat, so that there is better load distribution. This will work in tandem with an aluminum frame placed around the edge of the mat to also provide support for the weight of users walking over it.

To make this design modular we will be using dovetail connections around the edge of the mat so that the mat can be extended on any of the four edges of the square. To make sure that the wiring can also be connected in any direction we will use a cable multiplier on two corners of the mat as shown in the Figure 1, so that having the option of either a male or female plug at two corners allows the power running through the previous heating cable to connect to the next one.

Finally, for ease of storage there will be a central line on the mat where it can be folded in half. There will also be a connection point near the central line, so that the wire can be pulled through and protected when the mat is folded.

### 3.0 Design 2

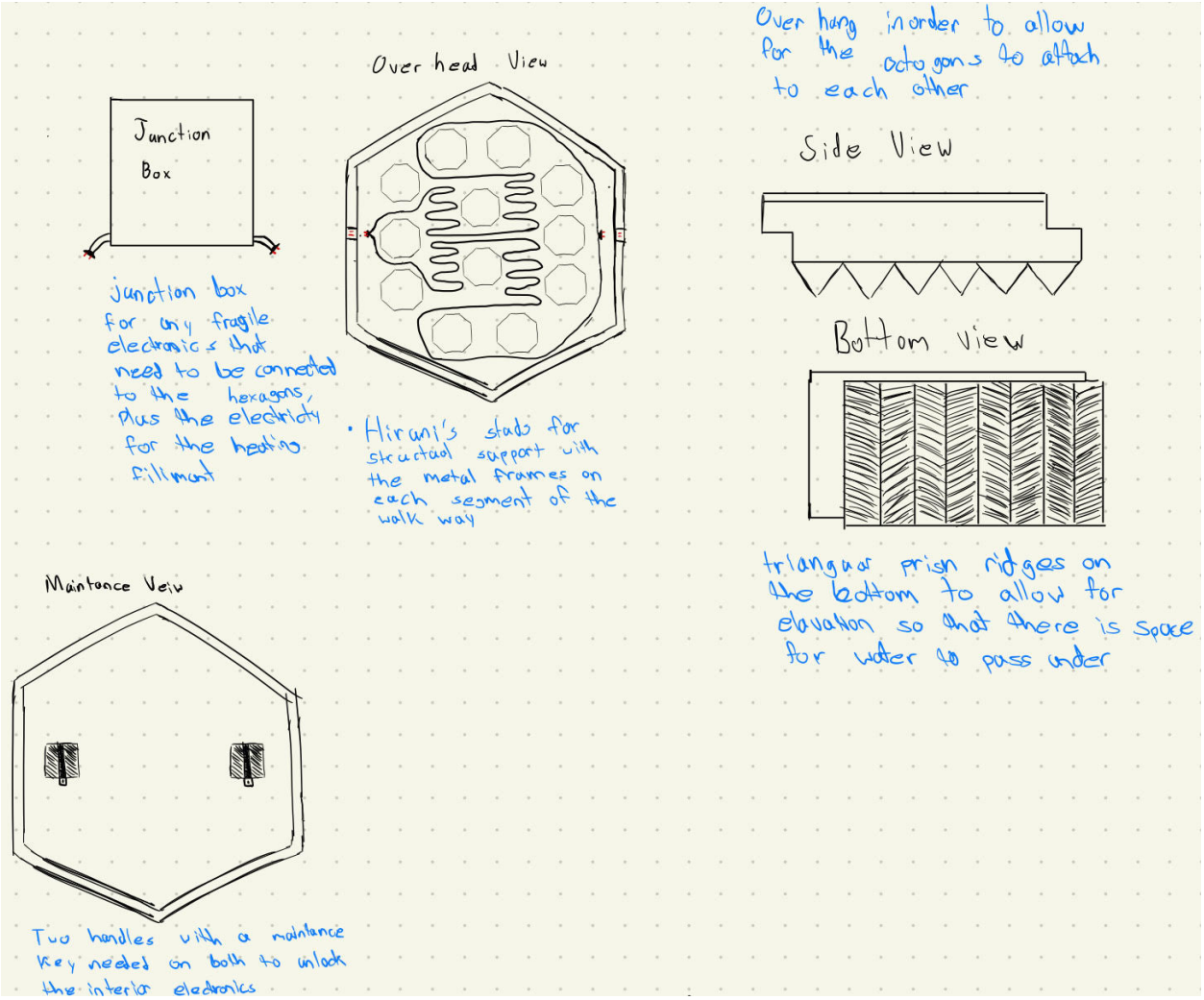



Figure 2. Sketches of the design concept 2

This design uses an electrical heating system, with metal wiring running throughout the inside of the hexagon, the power for the heating system will come from the junction box which will house the fragile electronic components that will serve to power the walkway that it's plugged into.

The structural integrity of the walkway is dependent on the stubs inside the hexagons, combined with the metal framing surrounding the outside of the hexagons, this allows for the necessary structural support to withstand a person's weight and the weight of snow and ice on top of the walkway.

This design allows for connections with other hexagons in order to create longer pathways, these connections are made using the designs overhangs and underhangs found on different sides of the hexagon this is also how the hexagons will transfer power from the one closer to the origin to the further one.

On the bottom of the hexagons there are triangular prisms that serve to elevate the walkway higher inorder to allow for water from the melted snow and ice to pass under. While on the top of each hexagon there will be two handles which will serve as the means by which a maintenance worker could open the lid of the hexagon using the maintenance key and access the interior of the walkway.

**4.0 Design 3**

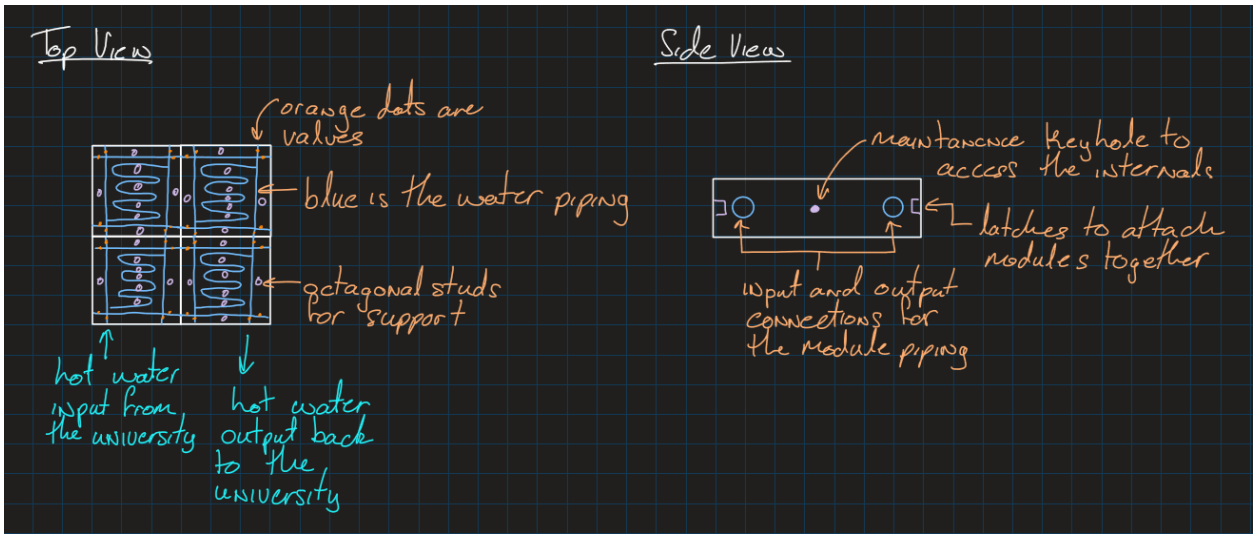



Figure 3. Sketches of the design concept 3

In this design, the team decided to explore alternative methods to melt the snow off the top of the modules. Here, there is an input pipe that would connect to the university's heated water supply which would utilize it to transfer heat to the snow and ice. The main piping in the module follows the previous designs by using a series of turns to evenly heat the module.

Another major difference between this design and the other two would be how the modules would be connected. A series of straight piping will be located along the perimeter, with valves at the end of each pipe. Each of these pipes will be the connections for transferring the fluid between the components, and the pipes would need to have a small fastener to secure them together. Additionally, a rubber friction seal will be surrounding the connections on the case to avoid any leakage and to prevent melted snow from seeping into the device. To control where and how the fluid flows, the valves will be available via a maintenance key to direct the flow and create a closed loop. To hold the modules together, a latch can be found on the side to keep them secure. For additional structure and support, metal bracings will be attached along the outside perimeter of the module, and studs to help support the weight can be found scattered throughout the internals.

## 5.0 Decision Making Process

To help us choose a final concept to move forward with we created a selection matrix using the specifications created in Deliverable C as seen in Table 1. Unfortunately, we didn't have many specification values that we could do without building and testing the concepts.

Table 1. Selection Matrix

| Specification | Importance (weight) | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|---|
| Easy of access (scale of 1 to 5, 5 being the best) | 5 | 4 | 4 | 2 |
| Number of connection points | 5 | 4 | 2 | 2 |
| Ratio of stored size to deployed size | 4 | 0.5 | 1 | 1 |
| Total | | 42 | 34 | 24 |

Thus, from the selection matrix we can see that concept 1 is the better design. Although before we move forward with this design we decided to create a pros and cons table as seen in Table 2, to further discuss the concepts since we didn't have many specifications to compare in the selection matrix.

**Table 2. Pros and cons of each design**

| Concepts | Pros | Cons |
|---|---|---|
| **Concept 1** | ● Can support heavy loads using the stud feature and the aluminum frame<br>● Can be plugged in any of the four directions<br>● Can be halved in size by folding for storage and the connection point protects the wire so it doesn't get damaged<br>● Dovetail connections make it easy to put together but really hard to pull apart so the horizontal tugging caused by people walking on the mat won't pull it apart | ● If the mat is placed against the edge of a wall the dovetail connections would cause there to be tiny gaps which can be a safety hazard<br>● Since the interior mat needs studs it will potentially need to be custom made |
| **Concept 2** | ● Due to its hexagonal shape, it allows for more unusual mat formations to be formed (ie/ can cover areas that are not perfectly rectangular or square) | ● Can only be connected in two directions<br>● The hexagonal shape will create gaps if it's lined up with the edge of a building |
| **Concept 3** | ● Can have multiple connection points throughout campus by connecting to the underground piping as convenient | ● Requires more planning for how the water will flow<br>● More labour intensive to set up<br>● Creating a heated water system out of scope for our team's capabilities right now |

## 6.0 Chosen Concept

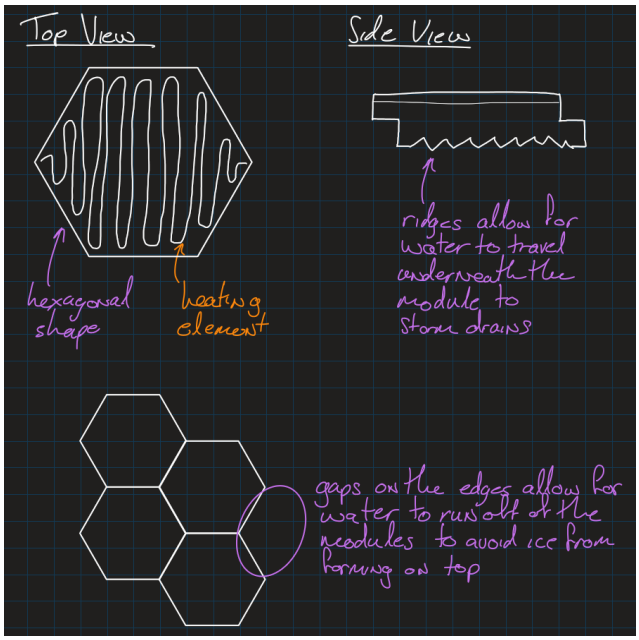
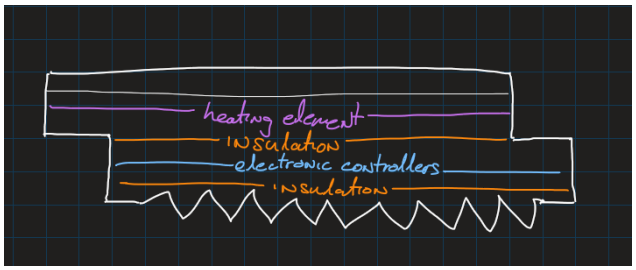
After doing both the selection matrix and the pros and cons table we decided to go forward with design one since it seemed to cover most of the client's needs, while being feasible for our team's current skills and the time constraint we have to build this design. Please refer to *Section 2.0 Design 1* for more information on how the design works.

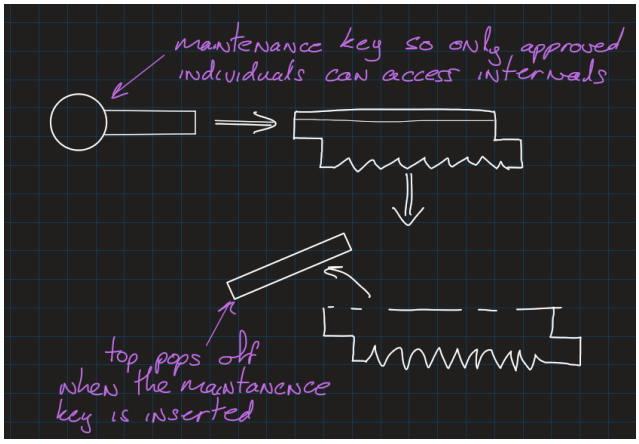
## Conclusion

In summary, the members modified and integrated all the individual designs according to the design standards, and finally got three designs that met the standards (design 1, 2 and 3 respectively). Design 1 uses the electric heating cable as the heating element, and the double-ended spiral provides support, which achieves a good load distribution and also provides great convenience for the maintenance of the designed system. Dovetail connections around the edge of the shield allows more matts to be attached, and the addition of a cable multiplier also greatly facilitates the ability to connect power to the next mat. The second design uses the hexagons as the main body of the internal structure, and the modules are linked to each other to drive each other, so that power transmission can be achieved. The wiring is densely connected to the junction box through the interior, so that it is evenly heated, and the electronic components in the box react and start to supply power. In terms of maintenance, the designer provides strong security and privacy. The technicians need to use the key to open each hexagonal manhole cover to enter the interior for maintenance. Design 3 directly connects an input pipe to the hot water supply of the school, and uses the heat of the hot water to melt snow water. Multi-angle pipes replace vertical pipes, so that the module is heated evenly, and the heating rate is greatly improved. The rubber friction seal prevents any leakage of liquid and solid, and important objects such as valves must be maintained before they can be opened with a key, which greatly improves safety. Each design guarantees customer needs and safety as much as possible, and strives to maximize benefits, but as a team we decided to proceed with building design 1.

**Appendix: Original Design Concepts**

**Arman**

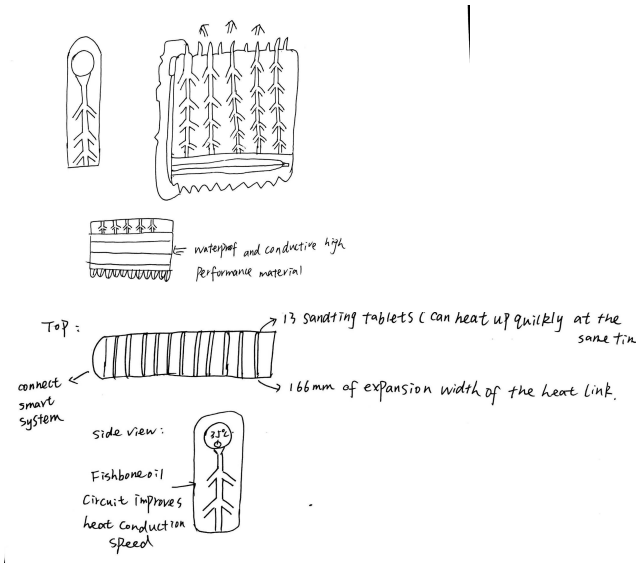
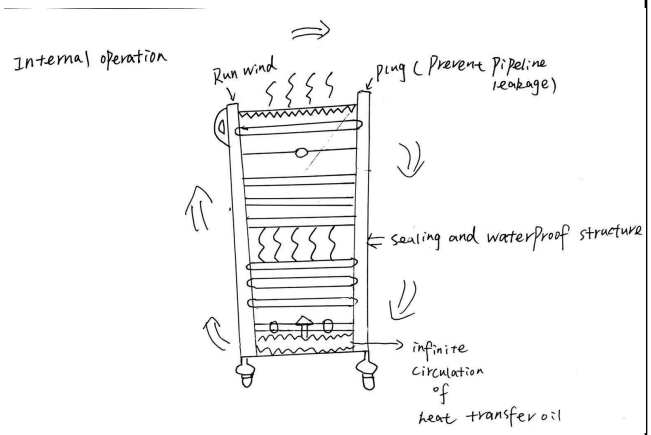
| | Drawings | Explanation |
|---|---|---|
| **External Design** |  | • A hexagonal shape will allow water to run off the model by the ends of the sidewalk or by the walls of a building to avoid ice formation<br>• Ridges underneath the model will allow the water runoff to flow towards existing storm drains<br>• Overhangs and underhangs will be on each side to allow modules to attach to one another |
| **Internal Operations** |  | • Insulated internals to protect all electronic components from significant changes in temperature<br>• Option 1) and Arduino uses a Bluetooth extension to receive live weather updates and turns on automatically when a storm is predicted<br>• Option 2) a "leader" module equipped with an |

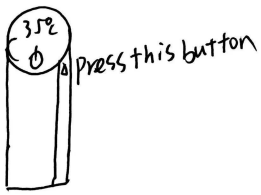
| | | |
|---|---|---|
| | | Arduino and a Bluetooth extension turns on via an app which will turn on all modules attached to the leader |
| **Maintenance Features** |  | • A maintenance key will be used to pop off the top cover to allow only approved individuals access to the internals |

**Group Notes:**

- Concerned about the gap edges on the sides of the hexagons for people with accessibility concerns
- The height of the hexagon could potentially be a tripping hazard and not wheelchair friendly if it's too tall (aim to have a height of 1-1.5 inches)

**Kristen**

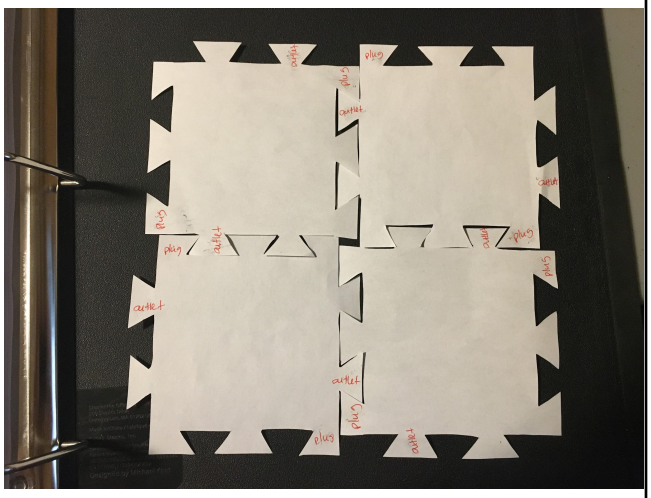
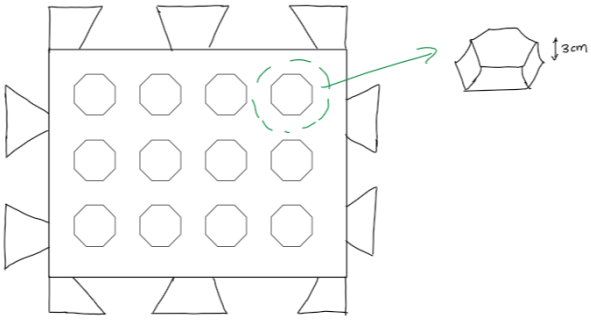
| | Drawings | Explanation |
|---|---|---|
| **External Design** |  | • Regarding materials, national standard fire-retardant materials(Such as specially treated polyurethane (PU), phenolic, rubber powder polystyrene, etc.0, the whole machine is made of flame-retardant materials, very environmentally friendly and safe. |
| **Internal Operations** |  | • The electric heating tube is installed under the cavity with many radiating fins, and heat-conducting oil is injected around the electric heating tube in the cavity. When the power is turned on, the heat-conducting oil around the electric heating tube is heated, |

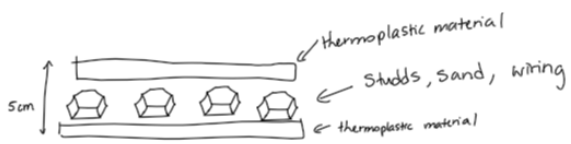
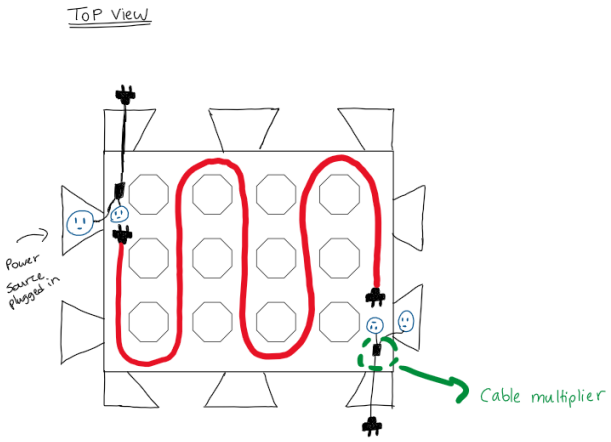
| | | |
|---|---|---|
| | | rises to the upper part of the cavity, and circulates convectively along the radiating pipe or fin, and radiates the heat through the cavity wall surface, thereby heating the space environment. The heat-conducting oil cooled by the airdrops to the periphery of the electric heating tube and is heated again, and a new cycle starts. |
| **Maintenance Features** |  | ● Just click this button, the system will connect to the smart machine to open the device, and the repairer can remove the contents for cleaning |

**Group Notes:**

- It seems more like a permanent solution than a removable solution since the creation of the fins seem like they will be expensive (product production is potentially expensive)
- While the components may work in combination with other designs this not really a modular walkway solution as asked for by the client
    - We can potentially take the idea of circulating heated fluid through a mat as our heating element

**Hiruni**

| | Drawings | Explanation |
|---|---|---|
| **External Design** |  | • Quad-directional mat using dovetail joints which allows them to easily be joined together but the horizontal force (tugging) caused by people walking over it won't pull the mats out of place since there is a bottlenecking effect (similar to dovetail joints in drawers during woodworking)<br>• The connection points are also hidden within the dovetails of the mat so they prevent tripping hazards (when 2 mats are joined together the connection point is secure within the dovetail) |
| |  | • Studded mat (similar to studded heat uncoupling membrane used when installing floor tiling) which has the following benefits:<br>1. Can wrap the heating wire around the studs to hold it in place and apart, by having the studs closer together so the wire has a tight fit |

| | | |
|---|---|---|
| |  | 2. The studs provide support for the thermoplastic material of the top of the mat so that when people are walking over it there is even load distribution and can bear heavy loads (proven bc this is the method used when using heavy large tiling) |
| **Internal Design** |  | • Custom make our heating filament so that it will fit any shape we decide the casing to be<br>• Nichrome wire as the conducting element<br>• Heat shrinking tube to incase nichrome<br>• Sand as an insulator to evenly distribute heat<br>• The downside is that each mat would be connected in parallel so if one goes out they all go out<br>• The heated wire is held in place on the mat using a similar design to the studded heat uncoupling membrane used when installing tile. They are hexagonal blocks used to string the wire around which will keep the |

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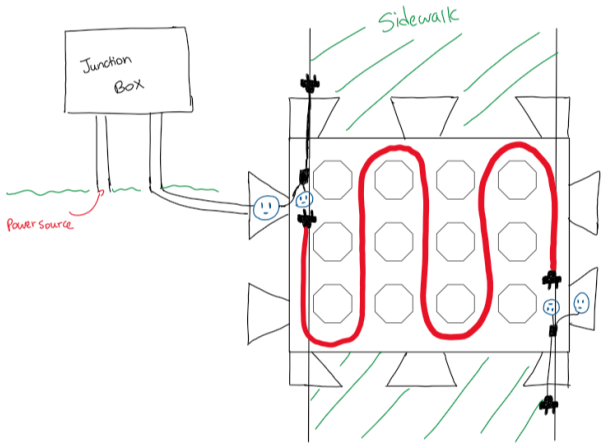
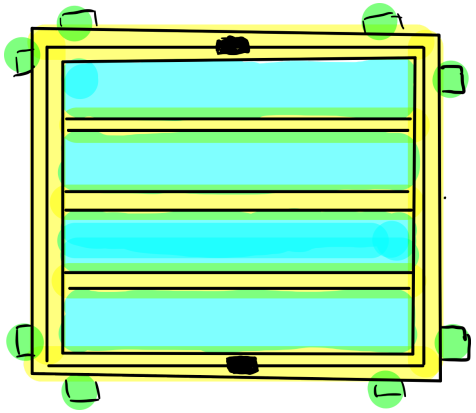
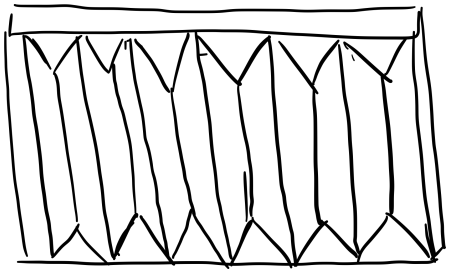
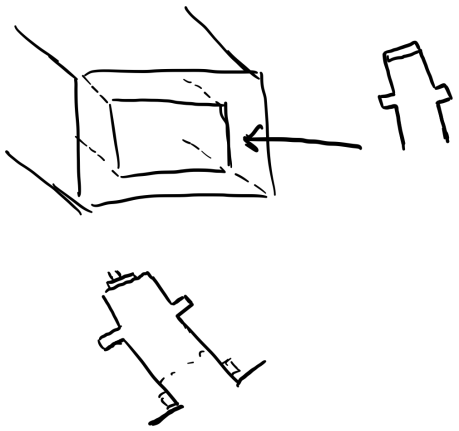
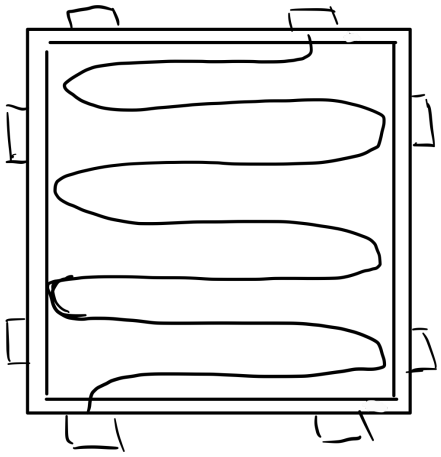
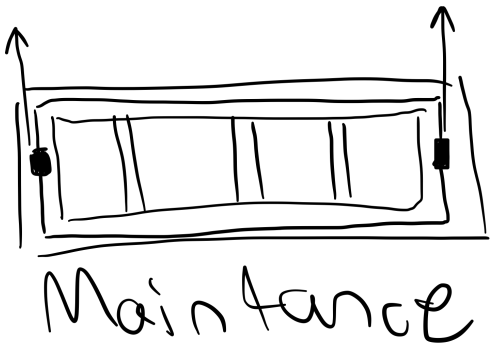
|---|---|---|
| | | wire apart (great for safety and not letting the wires burn)<br>● Uses a cable multiplier to offer an outlet and plug on two corners of the mat so it can be electrical connected in any direction |
| |  | ● Junction box (metal weather-resistant box) can be placed near the main section of where matting begins so that the power source and Arduino components are protected.<br>● Can contain Arduino bluetooth module, relay and power source contained in a circuit so that an app can be created where the user can choose to turn ON or OFF the mat which will send a signal to the relay to power ON or OFF the Arduino which will allow the power source to be used |
| **Maintenance Features** | | ● The studs are only holding the wire temporarily so it's easy for the maintenance crew to remove and replace a wire if it's damaged |

**Group Notes:**

- Would like to add a similar stud design on the top layer of the mat to provide grip (while keeping in mind wheelchair accessibility)
- When lining this up with the edge of the building, the gaps on the side could potentially be hazardous for people with accessibility needs (we can extend the square cover of the dovetails so that the gaps in the joints are covered)
    - Another option is to have a lot of dovetails so that the gaps are minuscule

**Stefan Ostojic**

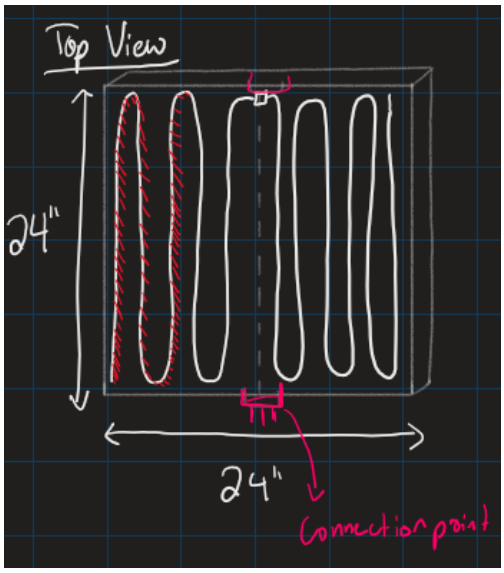
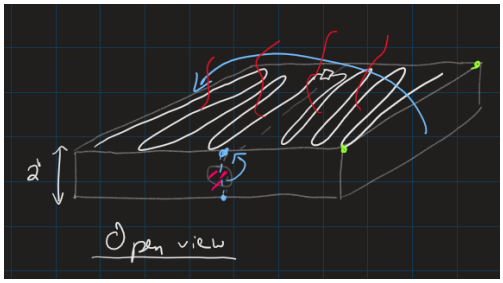
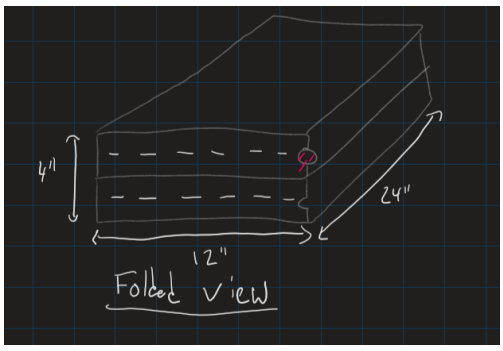
| | **Drawings** | **Explanation** |
|---|---|---|
| **External Design** |  | These are the conjoinis mechanisms that have two parreral sides enter the other two which joins them together making a conjoined walk way<br>A metal casing for the square walkway, for this part things such as nickel or titanium alloys would be good due to their cold resistance<br>This would be silicone rubber which would be the main part of the side walk that is used as a walk way |
| |  | This kind of bottom will allow for water to flow in between the edges |

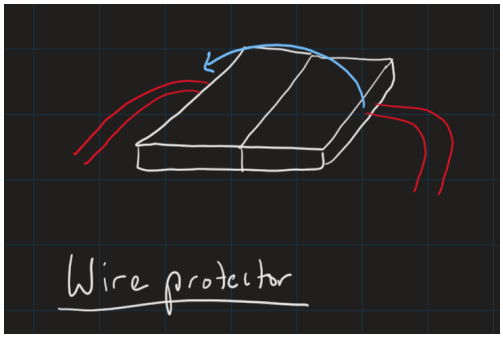
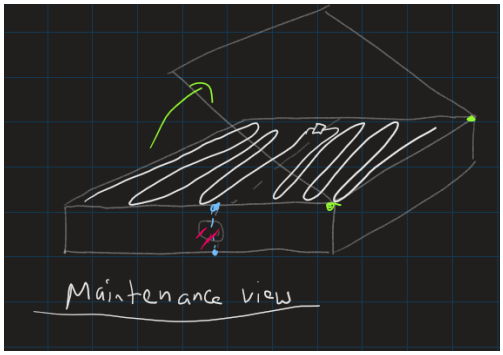
| | | |
|---|---|---|
| **Internal Design** |  | This joining mechanism has two points on its sides that once the two parts join the two points keep the parts conjoined and to realese the joint the button on the side of the part that entered is pressed and the part is then pulled out |
| |  | The blocks will open themselves on the top of the block to revel a winding pattern of copper wires going from one outlet to the other which can transfer energy from one square to the next using the joining mechanism |
| **Maintenance Features** |   | The the black bars are where the person would pull from in order to open the box for maintance with a key needed to be able to pull the top off |

**Group Notes:**

- If we want to fold this due to the aluminum frame we would need to have hinges
    - Probably use portions of the aluminum frame to provide extra support for users walking over it

**Paul Maciver**

| | Drawings | Explanation |
|---|---|---|
| **External Design** |  | • This view is meant only to showcase the lateral dimensions of the individual panels, as well as the basic idea of a heating coil running through the panel.<br>• The true surface shown would be covered in a thin layer of rubber, since rubber is not a good conductor of heat, but will be necessary in order to maintain traction in winter conditions.<br>• The connection point (highlighted in pink) is shown on the exterior for connections in a linear direction.<br>• Note the dashed line down the center upon which the panel can be folded. |
| |  | • This view provides a similar scope to the top view, this time defining the height dimension of the walkway.<br>• It also puts into perspective the fold that can take place for storage and movement purposes (represented in blue). |
| |  | • This view specifies how the panel would fold in half along the central axis. |
| **Internal Design** | | • The main internal design feature of note is the wire protector. Since the design is meant to be foldable, the goal is to prevent any damage that may impact the heating filament. Thus, this foldable piece will allow for both connection of the filament and safe |

| | | |
|---|---|---|
| |  | folding of the panel. |
| **Maintenance Features** |  | • Pinpointed in green are hinges at the top surface which allow the walking surface of the panel to be opened and the heating coil accessed. This makes each panel easy to repair in case of any damages. |

**Group Notes:**

- Lacks explicit mention of programming/hardware needed to operate the system
- Good concepts for storage, easy-access maintenance
    - Would maybe benefit from dove-tails as in Hiruni's concept