PD-J: Submission Presentation Notes

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3. Testing Project Plan - **Thomas**
4. Prototype quality **- Amenah**
5. Summary and prioritization of all issues and constraints - **Lucy**
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1. Introduction

Current Method

- Each year The University of Ottawa spends roughly 1.5 million dollars on snow removal.

At the start of this term, myself and the four other members of this team were given a problem that needed a solution.
The problem was that The University of Ottawa was spending roughly 1.5 million dollars on snow removal each year, and the method of doing it was not ideal.
Before and after each storm salt would be laid onto the surfaces that needed to be cleared and accessible.

- With concerns over the effect salt has on the surrounding nature an alternative is needed.

With concerns over the effects salt has on the surrounding nature and a need of having a more efficient method of melting snow, our team went to work on a new solution.
Problem Statement:
A solution is needed to quickly and effectively melt snow off of the sidewalks, high traffic areas and emergency exits at the University of Ottawa without compromising safety. The environment must be protected while still allowing this solution to be modular and scalable.

- As a team we have been given the job to design a heated sidewalk that is capable of melting the snow and ice on the sidewalks and entrances at the university.

  We came up with a solution to have a mat that uses electricity to heat the wires up that were coiled inside the mat, we wanted the mat to have the capability of being turned on and off using two sensors that would signal to the mat first if it is below freezing and second if there is precipitation. As a team we believed that this solution would be a good alternative to the current method being used.

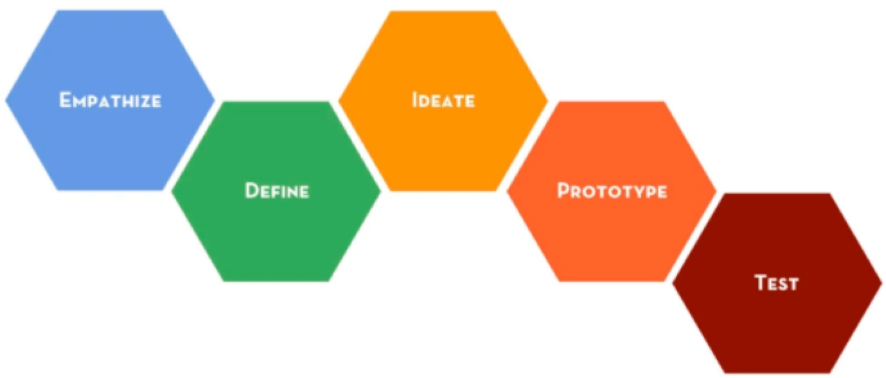
<u>Project Plan Outline</u>

Before we could start the design process we had to first determine how we would work and communicate effectively as a team. We were able to come up with multiple methods that could be used to achieve an effective design process, including:

- Wike
- Facebook Messenger
- Frequent Zoom meetings

2. Design Process

Our design process:



Recursive, iterative and continuous

- **Empathize:** Learn about the client for whom we can catering our design towards by various methods
    - Observation, interviews, group discussion
- Gather raw data form interview, observation, group discussions and user benchmarking.
- From initial background research we discovered that presently, in the market, there are 2 broad designs for heated sidewalk solutions.
    - Glycolic and electric, both with their individual pros and cons
    - User Benchmarking Glycol/Water Mixture Heated Sidewalks

Specifications	Glycol/Water Mixture Heated Sidewalks						
Company/Name	Hydronics.com	Therma-Hexx	Hydronic Snowmelt System	SIM Systems	Metrolinx: Glycol Solution Snow Melting System	Lee's Hydronics'	Watts Heatway

User Benchmarking Electric Heated Sidewalks

Specifications	Electric Heated Sidewalks					
Company Or Name	Roof Heating Systems: RHS Snow Melting Mat/System	Power Blanket: Summer step Home DM24x36C-RES Residential Snow Melting Heated Door Mat	Cozy Products ICE-SNOW Ice-Away Heated Snow Melting Mat	HeatTrak HR20-60	HOTflake Outdoor Heated Snow Melting Walkway Mat	SEAL Snow Melting Mat

- Both these designs had different specifications that were reseachered due to their extensive differences. Most comparison factors were similar to allow for an adequate specifications

- **01/27/2021** Client Meet 1: Group interview were the initial customer statements were derived a a table from which raw data was translated into the interpreted needs into likes, dislikes and suggested improvements
  - Interpreting Client's Needs from Client Meeting 1

Question	Customer Statement	Interpreted Need

- **Define:** A point of view was created based on the user needs and insights via analysis
- These interpreted needs were categorized and ranked by importance in order effectively organised and used in ranking different market designs by importance
- Created a problem statement that serves as commun goal within our team for the functionality of our final design and helps all members of the team stay on task.
  - *A solution is needed to quickly and effectively melt snow off of the sidewalks, high traffic areas and emergency exits at the University of Ottawa without compromising safety. The environment must be protected while still allowing this solution to be modular and scalable.*
- Customer needs were ranked by importance...
  - Ranking the Customers Needs by Importance

Number	Need	Importance
1	Drainage system	5
2	Clear snow/ice off quickly	5
3	Ability to be deconstructed	4
4	Easy to assemble	4
5	Easy to maintain	4
6	Safe to walk on	5
7	Low cost	2
8	Safe for the environment	4
9	Ability to keep salt and sand off the surface	3
10	Energy efficient	2
11	Storable	2
12	Durable	4

- These interpreted needs were then translated into solidified design criteria…
  - ***Translation of client needs into applicable design criteria***

Number	Need	Design Criteria

- ...which were then further organized into design specification categories; function requirements, constraints and non functional requirements.
	Design Specifications	*Relation (<,>,=)*	*Value*	*Units*	*Verification method*

- Technical benchmarking was done and all results were put into tables and organised using a simple tricolour ranking system
  - ***Colour Legend for Ranking Scale***

Good = 3
Average = 2
Bad = 1

- Results from the technical benchmarking were organised and the importance factor was taken into account in order to determine which designs would be best suited for the client based on his identified needs (derived from customer statements).

User Benchmarking Glycol/Water Mixture Heated Sidewalks Ranking by Importance

Specifications	Importance	Glycol/Water Mixture Heated Sidewalks						
Company or Name	N/A	Hydronics.com	Therma-Hexx	Hydronic Snowmelt System	SIM Systems	Metrolinx: Glycol Solution Snow Melting System	Lee's Hydronics'	Watts Heatway

User Benchmarking Electric Heated Sidewalks Ranking by Importance

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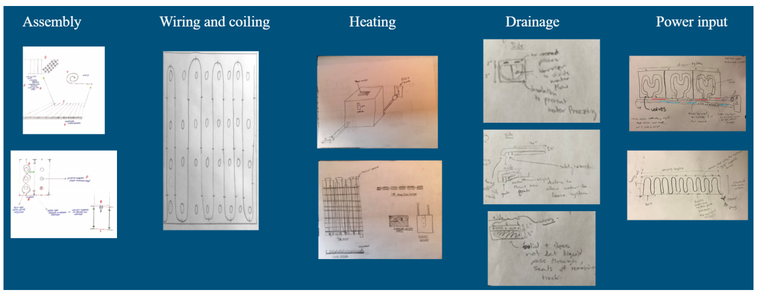
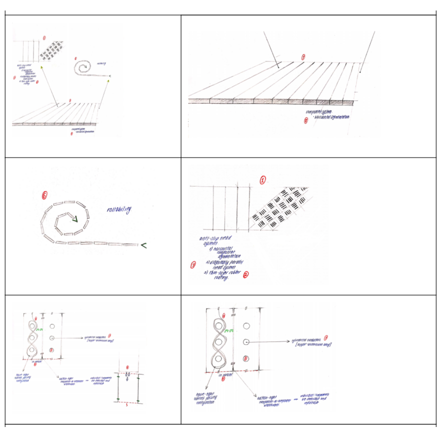
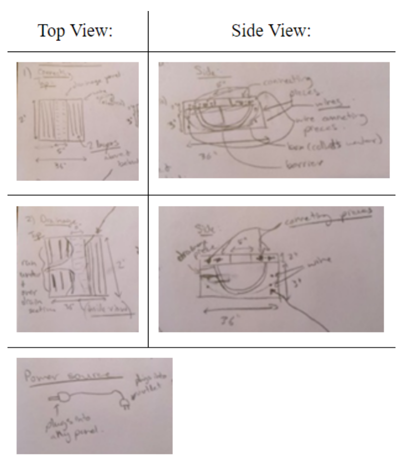
- <u>Result:</u> Based on the research provided, the overall design system that satisfies the design criteria is an electric-based system. The design of the system is easier to install and remove and more cost-efficient compared to the glycol/water system. The overall technical benchmarking process provided sufficient insight on previously designed products to narrow down the design criteria to the most feasible option, in determining the design specifications.
- **Ideate:** Brainstorm and come up with as many creative solutions as possible
- First, individual brainstorming was completed upon 5 pre-determined subsystems.
    - 

- In a formal setting, a group brainstorming session was held
    - Through collaboration, communications and augmentation, we came up with a prilimarlity solution as well as re-indeificed our subsystems into 3 subsystems
- Many, many sketch, block diagrams and mind maps were created for our solutions
    - Advantages and disadvantages were identified and further analysis was always continuous
    -  

- All data and ideas were categorized/condensed/combined/refined/reconsidered continuously
- Analysis and assessments of effects or results was done and organised by priority as appropriate
- Comparing different concepts as well
    - Divergent and convergent
- **Prototype:** Build a representation of subsystems and acquire feedback in order to proceed to the final solution
    - Built 3 prototypes of all 3 pre-determined subsystems
        - Assembly, drainage, electrical/heating

- Both physical and analytical (computer-based via OnShape) was updated with each prototype
- Testing at the completion of each prototype was done in order to determine its functionality individually as well as integrated within the full design solution.

Prototyping Test Plan

Test ID	Test Objective (Why)	Description of Prototype used and of Basic Test Method (What)	Description of Results to be Recorded and how these results will be used (How)	Estimated Test duration and planned start date (When)

- **Test:** Share your prototyped idea with the user and obtain feedback to improve the final design solution
    - 02/26/2021: Group presentation of solution
    - 03/10/2021: Individualized feedback session
- Using the given feedback, we defined the final prototype of our design solution and determined to contraitans, weakness, future goals and improvements as well as the most valuable areas.

3. Testing Plan

- Testing was a very important part of this project
- For many of us in our group, this project was the first time we have had to apply our knowledge in a practical way through building something
    - This made testing our prototypes even more necessary because we don't have the experience to know what will and will not work without trying it for ourselves.
- Knowing that there would be a lot of testing required we focused a lot of our time into creating testing plans so that we could get the most out of our testing. We had a short time in between deliverables and knew we had to correct any mistakes early on if we wanted to get everything done on time.
- Below is a section of our test plan and shows how it was laid out:

Test ID	Test Objective (Why)	Description of Prototype used and of Basic Test Method (What)	Description of Results to be Recorded and how these results will be used (How)	Estimated Test duration and planned start date (When)
Prototype 1: Assembly subsystem				
1	Stability of assembly	Determine how much water pressure could the basis structure withstand without any changes to its structural integrity	Dishwasher cycle was run three consecutive times in a row (3 with cold water and 3 with hot water). No started/corrosion proof was seen. Edges and assembly remained intact. Physical testing will yield better results as analytically calculating the force at any given point through a cycle would overcomplicate the test	6 hours per water type (hot and cold). 12 hours total (no supervision necessary). Date tested: 03/07/2021
2	Durability/Strength of material	Using bus bin structure as the basis, withstandable weight was measured by adding circular weights and recording this data. Place weights at the center of the structure and ensure even distribution for accurate results.	Both an analytical and physical test is required to obtain specific measurements. Weight capacity is physically tested for whereas volumetric capacity is calculated from physical measurement. The basis structure withheld 35 pound weight capacity; 4.63 gallons volume capacity.	20 minutes to add weights and record data. Date tested: 03/07/2021
Prototype 2: Drainage system				
3	Efficiency of drainage system (water in)	Holes were made into the bus bin structure (with heat) and the volume of liquid input was compared to liquid caught as output. **This test is made on an initial prototype thus the results are approximations** Testing was done 5 times and the average was used in calculations	Calculation of results using averages Input (L): 1; Out (L): 0.99; % Eff.: 99% Observed that the water imputed flowed relatively quickly through the grate system created.	30 minutes to input liquid at the greeting system, record initial and final volumes. Date tested: 03/07/2021
		As the piping has not been shipped from the supplier (Home Depot), a similar pipe		

- *The first* prototype was a very general one made out of cardboard. This allowed us to test:
    - How each panel connects to one another

    - Gave us something visual for our client meet
    - Let us see the shape in real life.
- This proved very useful and set us up for the next prototype where we could create the drainage system. This was the first focused and physical prototype that would make its way into the final design.
    - The rate at which water was removed from the system was tested and a graph was made. This let us change the angle of the pipe resulting in a more efficient design.
    - Many connections were not sealed and this allowed water to get into the bottom of the panel. This was corrected by sealing all the joints with silicone and drilling a few small holes into the bottom of the panel to let any excess moisture out to prevent the panel breaking if ice forms.
    - This proved to be the most useful prototype when creating this project
- *The third* and final prototype involved creating the control panel and connecting everything together. This was a comprehensive physical prototype that we would be using for design day.
    - This prototype was where we got to test that everything works together.
    - We tested the sensors by going into a big freezer and using the serial monitor in the arduino IDE to test that the sensors were showing the correct data for the conditions they were in. This was recorded in a chart:

	A	B	C	D	E
1	Temperature (F)	Precipitation	Power State	Deg. C	
2	70	DRY	OFF	21.11111111	=(A2-32)*(5/9)
3	67	DRY	OFF	19.44444444	
4	66	DRY	OFF	18.88888889	
5	62	DRY	OFF	16.66666667	
6	62	DRY	OFF	16.66666667	
7	59	DRY	OFF	15	
8	57	DRY	OFF	13.88888889	
9	56	DRY	OFF	13.33333333	
10	53	DRY	OFF	11.66666667	
11	51	DRY	OFF	10.55555556	
12	50	DRY	OFF	10	
13	48	DRY	OFF	8.888888889	
14	45	DRY	OFF	7.222222222	
15	42	DRY	OFF	5.555555556	
16	41	DRY	OFF	5	
17	39	DRY	OFF	3.888888889	
18	35	DRY	OFF	1.666666667	
19	33	DRY	OFF	0.5555555556	
20	32	WET	ON	0	
21	31	WET	ON	-0.5555555556	
22	29	WET	ON	-1.666666667	

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- With the electronics working and the drainage part of the panel built and tested all that was left to do was plug in the heating wire and make a surface for the panel where people would walk on.
    - With this done the system was finished and fully functional.
- Testing takes a lot of time and this process has taught the group that the prototype needs to be completed early on to allow enough time for the testing and making the necessary changes.

4. Results from Testing Drainage System, and Prototype Quality & Final Specs

Testing Drainage System (and results)

- Tested by flowing varying volumes of water through pipes with varying slopes
    - Droplet - simulates snowmelt condition
    - 4 L - simulates heavy precipitation

Note: pipe slopes were adjusted until max drainage was determined

Table 1: Measured pipe properties

	Length		Diameter		Cross-sectional Area	
Pipe	(in)	(mm)	(in)	(mm)	(in2)	(mm2)
Black	12	304.8	3	76.2	7.07	2280.18
White	17	431.8	3/4	19.05	0.44	285.02

Table 4: Time taken for one droplet of water to travel through the black drainage pipe (2:1 slope)

Trial #	Volume of water, V, (L)	Time taken for water to flow through the black pipe, t		Flow rate, Q, (L/min)	Flow velocity of droplet, v, (mm/min)
		(s)	(min)		
1	0.001	0.53	0.0088	0.11	49.65

Table 5: Heavy flow of water through the Drainage System as a whole

Trial #	Volume of Water (L)	Time taken for water to flow through the drainage system		Calculated Flow Rate (L/min)	Estimation of type of flow	Volume of water collected from white pipe (L)	Percentage of water collected from white pipe, from total flow (%)
		(s)	(min)				
1c)	4	19.4	0.32	12.5	Medium/ typical	3.38	85
2	4	10	0.17	23.5	Fast	3.41	85
3	4	24.5	0.41	9.8	Slow	3.40	85
Average flow collected from white pipe:						3.4 L	85%

Final Specs

- Panel/Storage Dimensions (L x W x H): 18.75 in x 15.5 in x 4 in

- Panel weight: 5 lbs
- Weight sustained by panel: 0 - 190 lbs
    - Further testing required to see weight sustained at failure (i.e. max weight)
- Heating temperature: 25°C at -20°C surrounding temperature
    - Heating time from 0°C - 25°C : 2 min
- Average melt rate of snow/ice: 33 g/min
- Range of drainage rate:
    - Min tested: 0.032 L/min (droplet)
    - Max tested: 23.5 L/min (heavy flow)
- Coldest surrounding temperature without affecting function: -40°C
- Cost of one panel: $82

Prototype quality

Given the 100 CAD budget, our prototype is of overall good quality

Our prototype is:

- Functional
- Efficient at snow/ice removal
- Cost effective
- Environmentally friendly (low electric usage)

Potential improvements in quality to compete with heating mats in the market:

- Increase surface roughness to further minimize slippage
- Flatten and enhance aesthetic appeal
- Others - explained in Reflections

5. Summary and prioritization of all issues and constraints

- BOM and budgeting
    - The importance of scheduling, budgeting and planning was a huge take away for Team 5 throughout the prototyping phase.
        - 1) One of the constraints was that the products were all purchased at once, instead of assembly one subsystem at a time and purchasing parts when they are needed. This was due to the fact that one out of all 5 team members was responsible for the assembly of the final product, therefore these products were purchased on their own time.This hindered the possibility of maximizing the budget in terms of replacing components during the testing phase if something were to go wrong.
        - 2) Another constraint was the BOM listed was a general description of the products purchased for the design presented, however depending on the location purchased and the store the cost will vary, as well as the

        availability and quantities at said stores. This hindered our budget as some products were more expensive compared to others.
    - Team 5 was able to overcome these limitations by:
        - 1) Making use of the materials that were purchased, modifying the design to allow for maximum use of the components.
        - 2) The team was able to follow the BOM to the best of our ability, luckily the materials purchased were still all under budget.
- Panel Height
    - The height of the panel is currently dependent on the base container used. The height of the container is not an ideal height for the overall product. The following limitations are:
        - 1) The system is not very accessible to enter and exist
        - 2) It presents a potential tripping hazard
        - 3) The large height difference can allow for the snow build up between the ground level and the panel, which can reduce and waste the heat energy.
    - Team 5 was able to overcome these limitations by:
        - 1) Using the same material that was used to create the surface panel, a ramp was created for easy access on and off the platform to allow for easier accessibility onto and off the panel, and to reduce the tripping hazard. This will also reduce the risk of snow or ice being wedge under the panel.
- Drainage system piping
    - The initial design allowed for a T-shape system (in the drainage panel) to collect and remove excess water from the system and be safely transported to a sewer drain. Due to budget constraints the updated design of the drainage system was not used for the final subsystem design. The limitations we came across in this design were as follows:
        - 1) The components for the final design were not all purchased due to budget constraints. Therefore, the T-shape design was not included in the final design.
    - Team 5 was able to overcome these limitation by:
        - 1) A pipe with a larger diameter was purchased and sawed in half (length wise). A hole the size of the second pipe (smaller diameter) was drilled in the side of the larger pipe to allow for the excess water to drain through the system. These pipes were assembled using PVC/plumbing glue, to ensure a tight seal.
- Sensor box component
    - The initial design allowed for one sensor box to be installed for a row of multiple panels (connecting and drainage panels). In reviewing the design, the placement of the sensor box may not provide an accurate reading due to:

        - 1) The box must be placed above the panel/potential snow bank, as it cannot be buried beneath the snow - to prevent an inaccurate temperature reading and to prevent the system from overheating/failure.
        - 2) The box will be at the end of the panel chain, closest the power source (wall outlet) - this could potentially result in an inaccurate temperature reading if the sensor is placed on the exterior of a building, as well as inaccurate precipitation reading if the sensor is located underneath a roof platform, preventing snow or rain access.
        - 3) The box sensor also risks a build up of snow or ice on the sensor.
    - Team 5 was able to overcome these limitations by:
        - 1) Increasing the length of the wire between the box sensor and the first panel - to allow for the box sensor to be placed above the panel (ground level) and reduce the possibility of the box sensor being buried beneath the snow.
        - 2) Throughout the testing phase, the box sensor was placed within the same environment as the panel to determine if the sensors were fully functional under said conditions.
        - 3) The accumulation of snow or ice is a factor that depends on the environmental factors - mindful placement denoting within the user manual to avoid such events.

6. Conclusion

- Future modifications (within and outside of the budget)
    - Within the budget:
        - Allocate the BOM to one or two individuals who will be responsible for purchasing the desired components. This will allow them to contact local stores and ensure all components are available and at the proper listings. As well as individually plan out when each subsystem will be developed and purchase the materials accordingly, as opposed to all at once. Finally, to develop more thorough contingency plans, updating these throughout the entire project process.
        - The base panel could be reduced in height, if cut in half with the proper tools. This would reduce the height of the panel and the distance between the heating wire and the surface panel.
        - The gutter pipe would be attached and sealed with the remaining PVC/plumbing glue to the surface of the panel to prevent the possibility of excess water leaking throughout the system. This would reduce the overall height of the panel base. This would also allow for the drainage system to be removed with the surface panel when opening the system.

    - Placing a form of the heating wire within the electrical box to allow for the sensor to remove ice and snow accumulation.
- Outside the budget:
    - To redo the BOM with the local store pricing and purchase the components for the updated design (T-shape component).
    - A 3-D surface layer panel would be created that allowed for a ramp option to be deployed when the mat is in use, as well as stored up and under when the mat is not. The base would also be 3-D printed to a smaller height.
    - The final design of the drainage subsystem would be implemented, the T-Shape plumbing. The larger diameter pipe would be fitted to the surface panel and sealed to prevent water leaking within the system. The gutter pipe would also be connected to the T-shape system from the bottom, with the proper fittings (similar to the connection in the product presented to the client).
    - Ideally, the team would integrate a sensor for each panel into the base of the panel to accurately determine the exact temperature and amount of precipitation on the panel. This would require a different material to be used throughout the top section of the panel and an arduino kit to be included within each panel - the panels sensors would be independent of each other in terms of heating the individual panel and an overall on/off function setting to allow for the panels to be manually overridden and turned off.