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CUSD Sustainable Mobility - Shelter
Fall 2019

CORNELL UNIVERSITY SUSTAINABLE DESIGN

Cornell University Systems Engineering

GRADUATE PROJECT REPORT

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Mobility Team - Shelter

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Preface

The overarching Sustainable Mobility team is a part of Cornell University Sustainable Design (CUSD) and is dedicated to re-designing public transportation in Tompkins County, New York. This interdisciplinary team, comprised of both undergraduate and graduate students from Cornell University, is advised by Sirietta Simoncini.

With the Sustainable Mobility team facing an increasing number of projects to tackle, we decided to forgo the traditional team-wide report and divide into three subteams: Shelter, Garage, and Electrification. This report focuses on the Shelter team. Within the shelter team, we further divided into two subteams: Shelter Design team and Master Plan.

The Shelter Design team has been working for the past 3 years on creating a student designed, solar powered bus shelter. Available in three different sizes, the shelter combines academic and practical skills that students from a variety of disciplines have honed throughout their time at Cornell. The shelter is currently in the prototyping phase, and representatives from the Shelter Design team, along with the Master Plan team, have been in contact with Cornell Transportation and Cornell Landscape Architecture to discuss the potential of implementing the first shelter on campus.

The Master Plan team was formed in Fall 2018 at the suggestion of Tompkins Consolidated Area Transit (TCAT), our stakeholder. Currently, TCAT has no database to assess the condition of their shelters in all of Tompkins County. The Master Plan team was formed to address this issue.

In addition to cataloging the current TCAT stops and shelters, the Master Plan team aims to use this information to find a location for the shelter that the Shelter Design team has been working on. While the long term goal of the Master Plan is to observe all of the stops and shelters in Tompkins County, we started off focusing on the locations in and around the Cornell campus. Thus, over the course of the semester, the Master Plan team determined two potential locations for shelter replacement: A-Lot on North Campus and Risley Hall Shelter. In the case of A-Lot, the Shelter Design and Master Plan team have come to the consensus that it would be best to consolidate the two existing shelters and replace them with one large shelter.

Context Diagram

In the coming semesters, the Master Plan team will continue to develop a system to determine where bus shelters can be placed. This semester, the team began gathering information and creating tools to inform what that system will be. One of the first tools developed to envision the system was the context diagram in Figure 1.

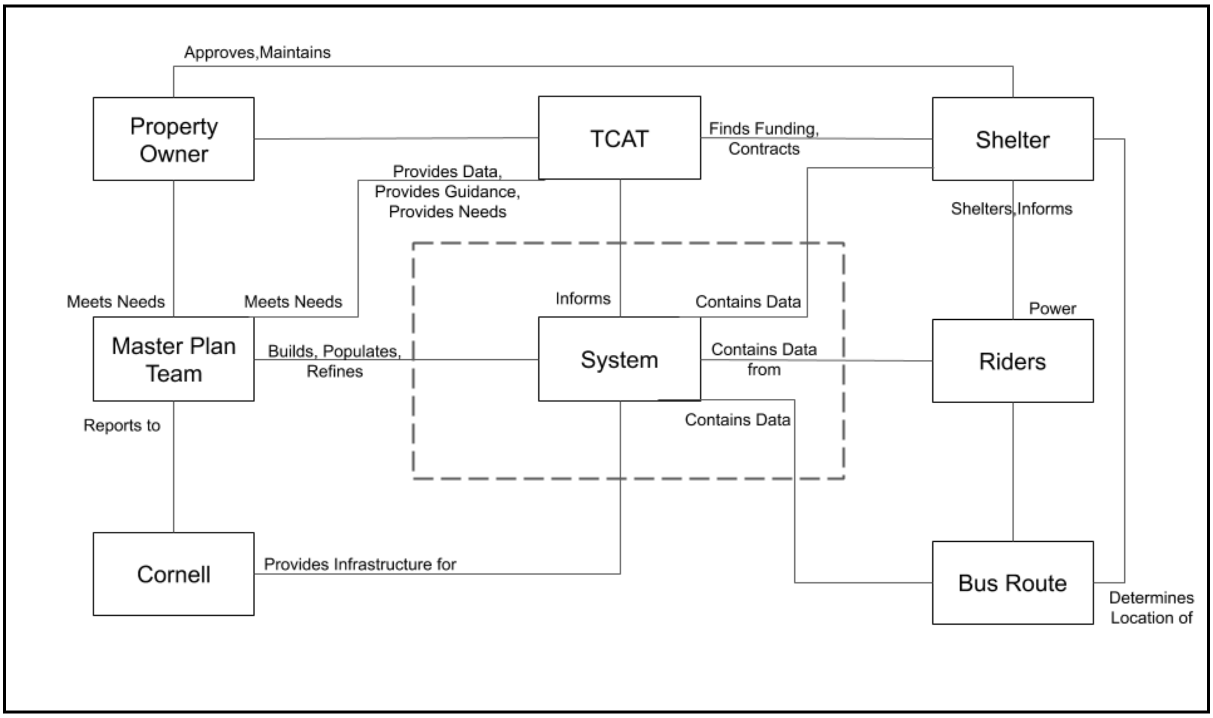

Figure 1: Master Plan Context Diagram

The context diagram helps to show stakeholder connections, while defining and clarifying the flow of information between entities. It describes a system that houses and displays rider and route data in a meaningful way. Meaningful in this context refers to something that informs and influences TCAT shelter construction projects. As shown in the user diagram, the Master Plan team will build this system. As such, important strides were taken this semester to determine what TCAT uses for shelter location decisions and in gathering data for the system.

The need to meet with TCAT during the semester and forge a stronger relationship with this key stakeholder was emphasized by the context diagram. A subset of the team met with TCAT this semester (detailed later in the report) to build understanding between teams. In this meeting, TCAT highlighted the importance of data-driven solutions. TCAT would like to expand the categories of data they use for future decision making beyond strictly quantitative measures - in addition to these more traditional metrics, TCAT would also like to incorporate customer experience into their models.

TCAT's desire to rely more heavily on customer experience for decision making underlies our motives for conducting the empathy fieldwork outlined in this report. This fieldwork allowed the Master Plan team to more thoroughly understand how riders interact with the bus system and allow for the development of a more useful bus shelter/route decision-making system.

While the Master Plan team continues to work on determining the rider experience metrics that would best inform shelter placement decisions, the team is also working to increase access to ridership and route data. Though TCAT wishes to explore the use of new metrics, the long-established criteria still need to be incorporated into any decision-making system. Working with a TCAT data expert, the Master Plan team obtained access to a limited subset of this data. This data was provided in a Tableau format. Because both TCAT and students on the Master Plan team have access to Tableau, it may prove a useful front end for the information system to be developed by the Master Plan team. However, further analysis of alternatives will be needed to be completed in the future.

Though Tableau may or may not be used in future Master Plan deliverables, the tool did prove to be a useful go-between during the Fall 2019 semester. It allowed for easy data transfer between TCAT and the Master Plan team, using Tableau public. Tableau also allowed the team to begin examining and manipulating the data. Doing so in Tableau, the data visualization in Figure 2 was developed. An interactive version of this tool is available on Tableau Public here: https://public.tableau.com/profile/terry.greene#!/

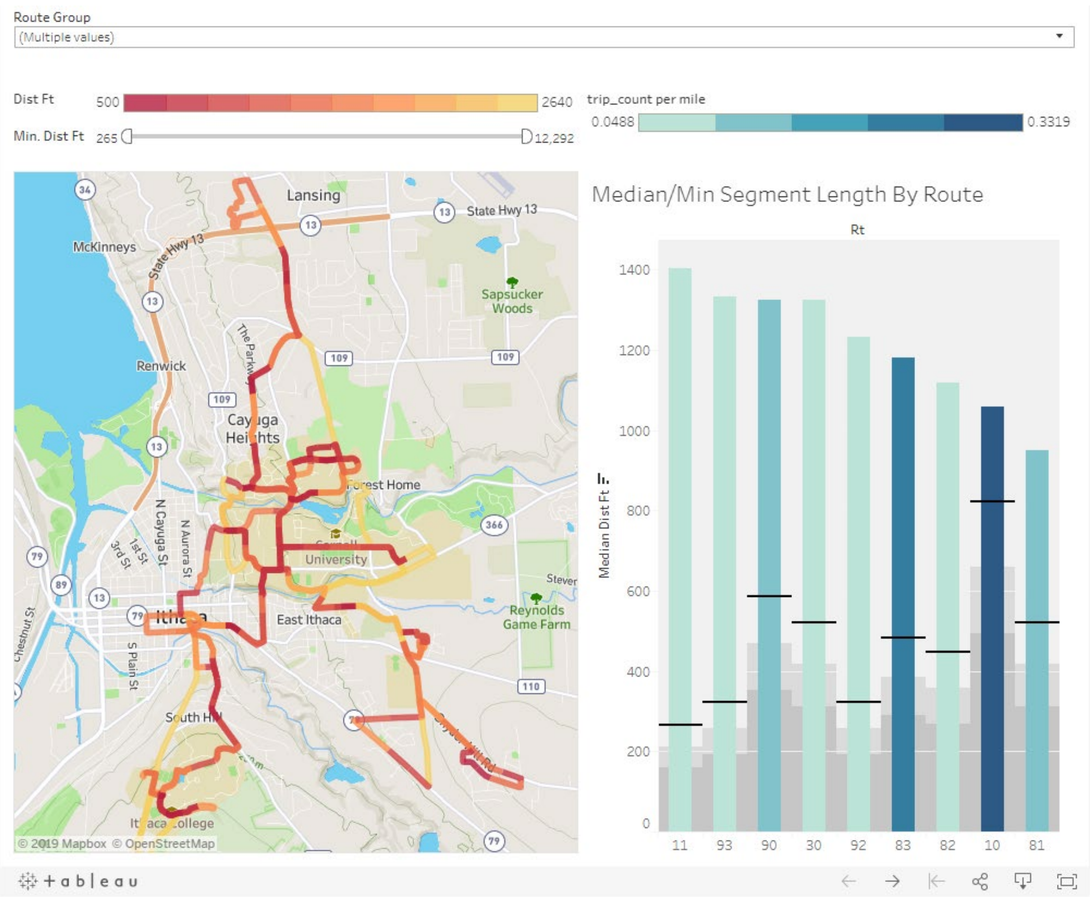

Figure 2: Example Tableau Visualization

During the Fall 2019 semester, the Master Plan team had somewhat limited access to TCAT data. One of the few ways they were able to analyze the bus route was by segment length. The Tableau visualization developed allows users to filter by route and trip count. This is one way in which data could be used to determine shelter location changes. Using this map, decision-makers can focus on shelters that are very close together (could potentially be combined to one) and shelters that are far apart (routes that may benefit from an additional stop). In the future, this may prove to be part of a larger decision-making system. This semester though the Master Pan Team used the simple Tableau example to get better acquainted with TCAT's data. The production of this tableau visualization also helped to show TCAT the value the Master Plan team can provide. This strengthens the relationship between the teams as the students seek greater access to TCAT data.

Customer Value Proposition

In order to address the increasing needs of reducing our footprint on the planet we have set our efforts to address one of the biggest causes of pollution, public transportation. In a collaboration of Cornell University CUSD Mobility – Shelter team, the Tompkins Transit Authority and the collaboration of the users of the public transportation system. Our top-level strategy has included analyzing the routes through the city, the traffic signs and in this specific scenario, the bus shelters.

Ithaca's shelter according to our empathy field work are old, hard to maintain, use electrical energy from the city, uninformative, are unwelcoming located in arbitrary stops. We are addressing each of these needs by building a shelter that is sustainable, modular, informative for the passengers and that make more people want to use the public transportation system.

We want to make sure our users can arrive at the bus stop, and just by looking at the shelter figure out the route they should take to their destination, whether that route active or not, and the estimated time of arrival of that bus. At the same time we want to make sure the city possess a tool to decide when is convenient to place one of the new shelters, where is needed the most, and have different configurations to account for the estimated amount of users.

By providing technical measures of performance we aim to prove our footprint can be lower, the city can have reasonable costs and more effective investments and our users can be excited to use our shelters and feel more comfortable about city public transportation.

Requirements

In order to better fulfill the needs of stakeholders and to provide better service to the TCAT passengers, it is important to understand what the requirements are. In sum, all of the requirements can be categorized into three major goals: a welcoming environment, comfort and convenience. To make the shelters more welcoming, seats, lights, information panels and more should be considered. In order to make the shelters comfortable, covers for rain/snow should be provided, and additional features such as ultraviolet-proof side panels should be considered. Additionally, in order to make the shelters convenient, bus information should be continuously updated and the locations should be properly determined. More requirements with details are included in the table below.

Index	**Originating Requirements**	**Abstract Function Name**
OR.1	The system shall be connected to electricity grid.	Electricity Connection
OR.2	The system shall be exposed to sunshine	Solar Charging
OR.3	The system shall be store the electricity in batteries	Electricity Storage
OR.4	The system shall detect the command to display bus info	Trigger
OR.5	The system shall receive updated bus signal.	Receive
OR.6	The system shall translate the original signal to displayable signal for screen.	Translate
OR.7	The system shall turn the screen on	Turn on Screen
OR.8	The system shall start displaying on the screen	Start Text Displaying
OR.9	The system shall display all expected bus arrival times in a loop on the screen	Arriving Time Display
OR.10	The system shall display current time on the screen	Current Time Display
OR.11	The system shall isolate wind from outside.	Wind Isolation
OR.12	The system shall isolate rain from outside.	Rain Isolation
OR.13	The system shall isolate 95% ultra violet from outside.	UV Isolation
OR.14	The system shall be mounted over10 cm to avoid water	Moisture proof
OR.15	The system shall accommodate 15 people	Accommodation
OR.16	The system shall provide seats for 6 people	Seat
OR.17	The system shall be able to charge 2 mobile devices	Socket
OR.18	The system shall detect brightness of the environment	Brightness Monitoring
OR.19	The system shall trigger illumination requirement when the outside brightness is lower than 3 lux	Brightness Trigger
OR.20	The system shall keep the light when the illumination requirement is triggered	Illumination

OR.21	The system shall turn the light off when the illumination requirement is not triggered	Light off
OR.22	The system shall detect battery power	Battery Detection
OR.23	The system shall send reminder to TCAT if battery power is lower than 15%	Low Power Reminder
OR.24	The system shall be chargeable to TCAT maintenance	Chargeable
OR.25	The system shall accommodate two battery units	Battery Number

Use Cases

To provide a guide for design stage, the team came up with 17 potential use cases of the shelter and estimated the relative priority for each use case. Each use case's priority is evaluated under the criteria of use frequency and significance. In the future, the design team can use these use cases as a guideline for their own work, with some metrics being of higher priority than others.

	Use Cases	Priority
1	The user can have a seat in the shelter	M
2	The shelter protects the user from the wind	H
3	The shelter protects the user from the rain	H
4	The shelter protects the user from the snow	H
5	The shelter protects the user from UV rays	M
6	The user can charge electrical devices in the shelter	L
7	The user can keep themselves warm by staying in the shelter	M
8	The user can identify where the bus stop is	L
9	The user knows about the routes served by the shelter	H
10	The user knows when the bus will arrive	H
11	The user can read books in the shelter	L
12	Disabled users can use the shelter conveniently	H
13	Shelter is lit so that bus driver can spot users	L
14	The user can press a button to acquire bus info	M
15	The user can see outside the shelter from inside	H
16	The user only has to walk a short distance to bus	M
17	The user only has to walk a short distance from their building	H

Use Case Behavioral Diagram

Snow and rain are common occurrences around Ithaca, and shelters should be designed with weather in mind. The behavioral diagram below shows how the shelters should work in the case where a rider is waiting for the bus while it's snowing.

User Case # 4	
User take shelter from the snow	
Initial Conditions	
It snows outside, temperature is low	
User walks to shelter	
Operator (User)	**System (Bus Shelter)**
User walks into the shelter	
	The heater keeps running
	The walls and ceiling keep snow out
User takes seat in the shelter	
User is onboarding	
Ending Conditions	
User leaves the shelter and gets aboard.	

Bus information (such as route information) rank as one of the most important things for a passenger using the system to know. Another high-ranked user case is to having it be possible for users to know when the next bus will arrive. The behavioral diagram below shows how a possible indication system would work to provide proper bus information to passengers.

User Case # 10	
User learn the arrivle time of bus	
Initial Conditions	
User doesn't know when the bus will come	
User comes early and needs to catch on bus	
Operator (User)	**System (Bus Shelter)**
User walks into the shelter	
	The indicator color is green - bus coming
	The LED screen shows the bus information
User is waiting in the shelter	
	The indicator color is red - bus arrived
	The LED screen updates the bus inforamtion
User is onboarding	
	The indicator color is green - next bus is coming
	The LED screen updates the bus inforamtion
Ending Conditions	
User leaves the shelter and gets aboard.	

The distance between a shelter and the passenger's home is another important factor that affects user satisfaction with the bus service. All shelter locations should be properly determined so that each shelter can cover a reasonable amount of area, thus making it so most passengers only need to walk a short distance. Below shows the behavioral diagram that shows how the shelter works with this user case.

User Case # 17	
User walk short distance from their buildings	
Initial Conditions	
User needs to take bus	
Operator (User)	**System (Bus Shelter)**
User determines what bus route he/she will take	
	Bus route information should be updated on map
User determines which stop he/she will go	
	The bus stop locations should be clearly shown on map
User walks to the bus stop	
	The bus stop locations should be well chosen based on the daily data and proper analysis
Ending Conditions	
User walks relatively short distance to the bus stop	

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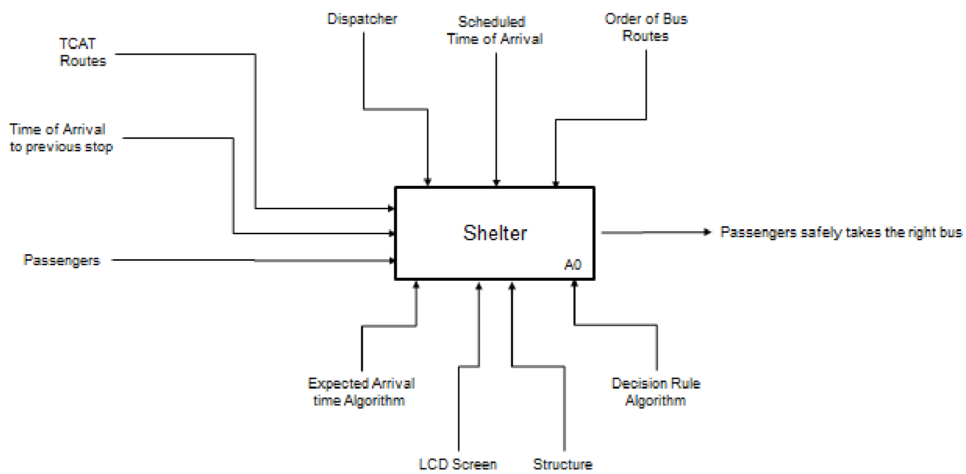
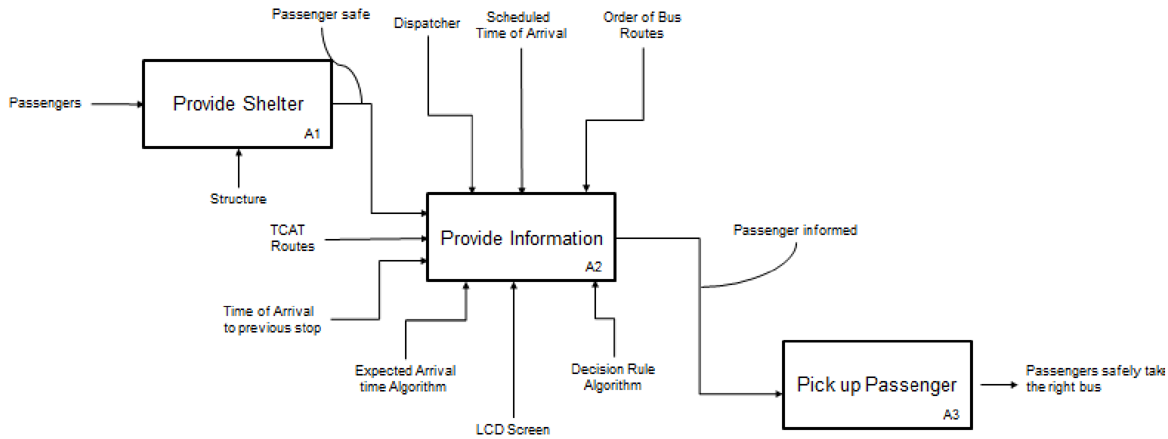
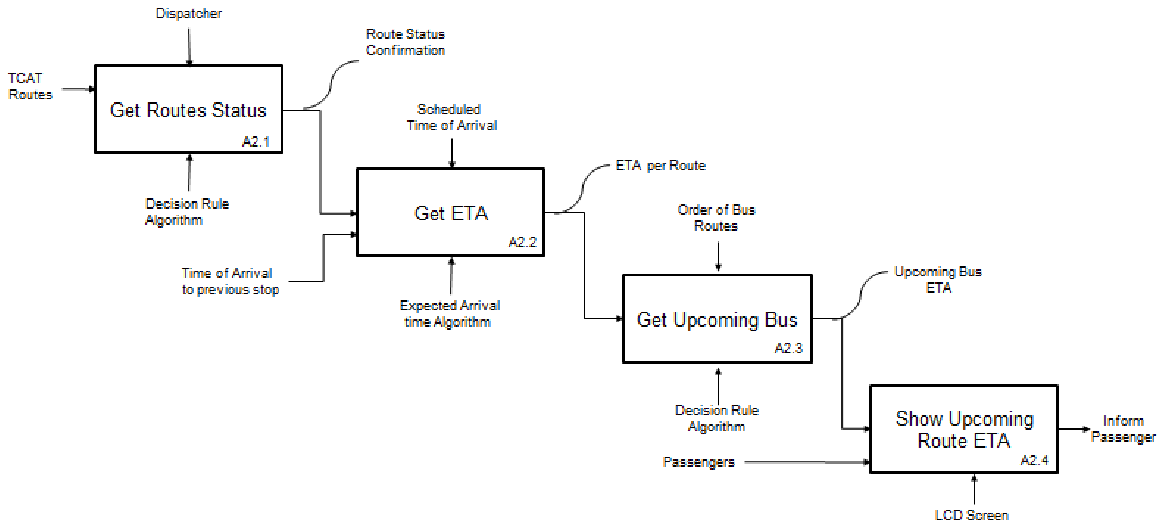



Passenger safe
Dispatcher
Scheduled Time of Arrival
Order of Bus Routes
Passengers
Provide Shelter
A1
Structure
TCAT Routes
Provide Information
A2
Passenger informed
Time of Arrival to previous stop
Expected Arrival time Algorithm
Decision Rule Algorithm
LCD Screen
Pick up Passenger
A3
Passengers safely tak
the right bus


Dispatcher
Route Status Confirmation
TCAT Routes
Get Routes Status
A2.1
Scheduled Time of Arrival
Decision Rule Algorithm
Get ETA
A2.2
ETA per Route
Time of Arrival to previous stop
Order of Bus Routes
Expected Arrival time Algorithm
Get Upcoming Bus
A2.3
Upcoming Bus ETA
Decision Rule Algorithm
Show Upcoming Route ETA
A2.4
Inform Passenger
Passengers
LCD Screen

Shelter Subteam

Mechanical Breakdown

Introduction

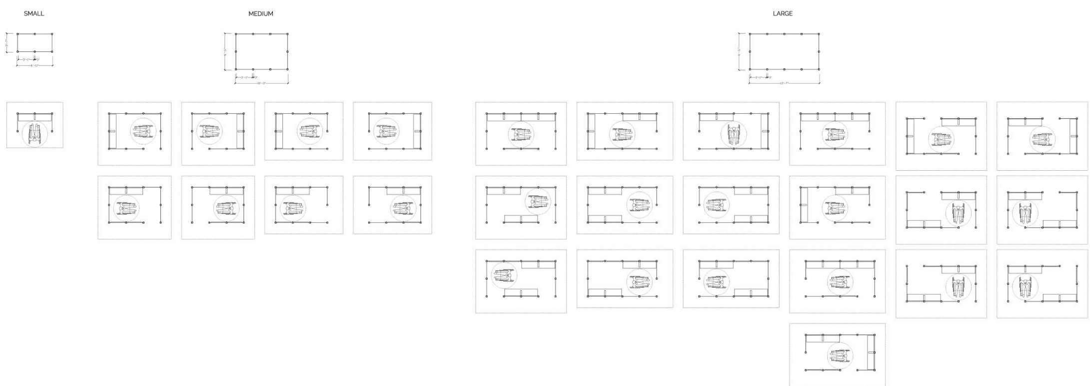
This semester we worked on fleshing out the details of the shelter. We've been working on the shelter for 3 years now and we've reached a point where we have a finalized design and are in the prototyping phase. Due to the size of the shelter, we wanted to avoid any issues that we could run into before wasting thousands of dollars that we could have foreseen. For logistical reasons, it made sense to put down on paper all exact details pertaining to the shelter, including all engineering drawings and manufacturing plans. In order to get the ball rolling for implementing the shelter in Ithaca and likely on Cornell's campus, we have received advice from TCAT and Taitem Engineering on how to do so. As a result, this report is compiled of instructions on how to build the shelter from the ground up.

Since there are many complex systems involved in our bus shelter design (namely mechanical, electrical, and digital), each section of this report will go in depth in each of these areas.

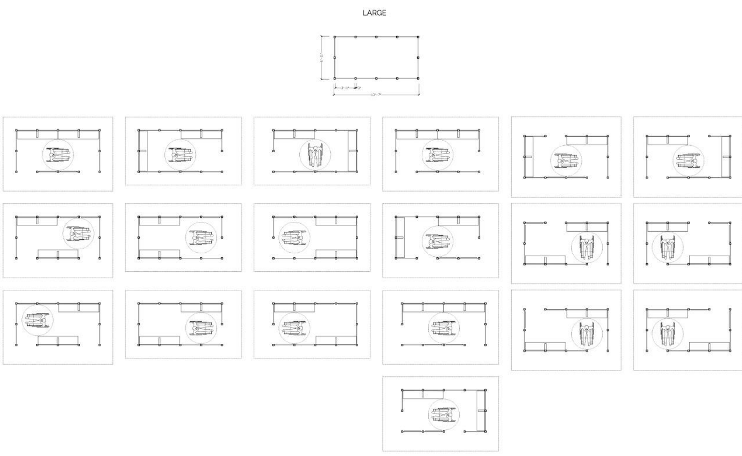
Our Shelter

As mentioned in previous reports, we have a modular design allowing for 3 different size shelters, a small, medium and large. All shelters used the same components, making it easy to upgrade or downgrade a shelter depending on the location.

The shelter can be broken down into 40 inch units, or modules, which serve as the basis for any shelter. The dimensions of each module was determined in order to comply with ADA regulations. To scale from a small shelter to a medium shelter and a medium shelter to a large shelter, additional modules are added.



Layout and feature variations of the small and medium shelter.

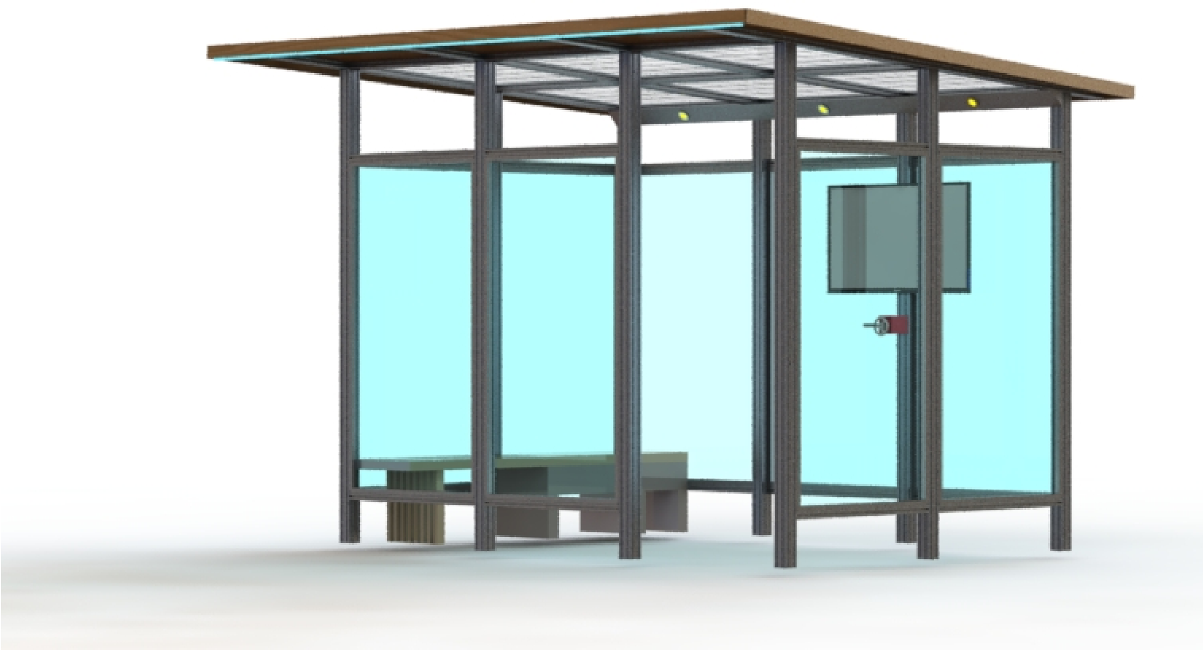


Layout and feature variations of the large shelter.

The modularity of the shelter also serves a practical role for assembly and part procurement, as it allows the process to be streamlined, leading to shelters that can be built more quickly while costing less.

We envision that our first shelter will be a medium shelter given the site locations that we are considering, so for this reason we focused our efforts this semester on the medium shelter. The following manufacturing plans are specific to the medium shelter. After getting our plans checked out by Taitem, we will procure manufacturing plans for the small and large shelters.

View of our Shelter



On Campus Shelter Site Plans

A potential location for the first prototype shelter is located in the A Lot on North Campus. The existing bus shelter placement consists of two relatively dated shelters located on opposite ends of the A Lot. The two shelters on the site lead to ambiguity on both the commuter and driver sides of the operation at the stop. Even regular commuters express confusion and dissatisfaction as to which shelter the driver will stop at; if the commuters initially choose the incorrect shelter, they must walk across the A Lot to the opposite shelter to board the bus on time. We are proposing to locate a medium shelter on the central parking lot divider in the A Lot. With this new location, we hope to eliminate the current confusion associated with two separate shelters. Additionally, the A Lot poses a great opportunity to showcase the collaborative student work of this organization to prospective students, visiting parents, and alumni during high traffic campus events such as Cornell Days.

This semester, a preliminary site analysis of the proposed location of the shelter was performed. The dimensions, slope, and nearby features of the site were recorded and plotted to evaluate feasibility of shelter construction. The site analysis of the central parking barrier resulted in the following conclusions:

1. The A Lot central divider appears to be large enough to place a medium or large shelter. The slope at the projected location close to the sidewalk appears to be gradual enough to place the concrete base of the shelter without costly landscaping operations.
2. There appears to be grid power at the site because there is a light post and ground enclosure for electric lines behind the projected location for the shelter. The possibility of access to the grid allows for flexibility in the addition of more power intensive features to the shelter without the limitations imposed by producing power only from the solar panels.

Future work on shelter site analysis must be conducted to finalize the appropriate size of the shelter and the municipality construction laws relevant to shelter placement. An analysis of the maximum number of occupants that use the shelters in the A Lot on a given day would aid in determining the necessary size of the shelter, as the current two shelters on the site are fairly large in size, but the regular occupation at peak times is unknown. It will be critical to thoroughly research municipal laws regarding shelter construction and placement, as well as the

feasibility of TCAT coordinating their bus stop locations to reflect the change in location of the shelter.

Structural Frame Plans

Our frame is modular, allowing for a small size, medium size, and a large size. In order to achieve this modularity, we make use of 80/20 profiles shown below:

Horizontal

1515-S	
Material	Aluminum
Grade	6105-T5
Finish	Anodize
Color	Clear
Drop Lock	2°
Moment of Inertia - IX	0.2631"^4
Moment of Inertia - IY	0.2631"^4
Surface Area	1.138 Sq. In.
Yield Strength	35,000 psi.
Modulus of Elasticity	10,200,000 Lbs / Sq. In.
Weight lbs	0.1109 per inch

Vertical

3030-S	
Material	Aluminum
Grade	6105-T5
Finish	Anodize
Color	Clear
Drop Lock	2°
Moment of Inertia - IX	3.3496"^4
Moment of Inertia - IY	3.3496"^4
Surface Area	3.109 Sq. in.
Yield Strength	35,000 psi.
Modulus of Elasticity	10,200,000 Lbs / Sq. In.
Weight lbs	0.3032 per inch

Roof Horizontal

1530-S	
Material	Aluminum
Grade	6105-T5
Finish	Anodize
Color	Clear
Drop Lock	2°
Moment of Inertia - IX	1.8127"^4
Moment of Inertia - IY	0.4957"^4
Surface Area	2.036 Sq. In.
Yield Strength	35,000 psi.
Modulus of Elasticity	10,200,000 Lbs / Sq. In.
Weight lbs	0.1985 per inch

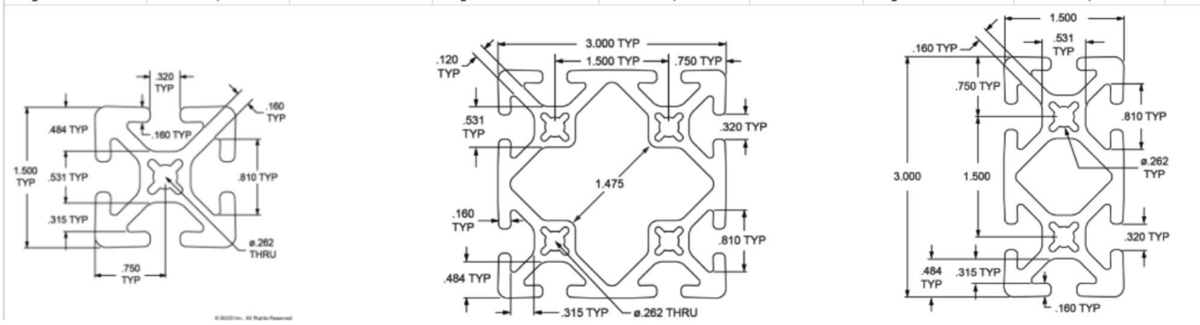


Figure 3: T-slot profiles

There are three different T-slot profiles used in our design for certain aspects of the shelter. According to Figure 1 above, there are mainframe, subframe, and roof-frame posts. The mainframe posts are 3030-S vertical posts that have a 3” x 3” cross-section, the subframe posts are 1515-S horizontal posts that have a 1.5” x 1.5” cross-section, and the roof -frame posts are 1530-S horizantal posts that have a 1.5” x 3” cross-section. These posts are joined together using butt fasteners, which is the strongest way to secure these profiles together. This attachment requires a counter boar in each of our 15-series subframe bars, only slightly increasing the cost.

Roof Racking Plans

One of the most unique features of the shelter compared to conventional shelters is the integrated solar panel roof. To support this standout feature, we chose to implement a custom racking system to mount the Lumos GSX 60/32 panels rather than purchase Lumos’ stock racking system. The decision to develop a custom racking system over implementing Lumos’ product was driven by the reduction of total parts and adaptors, reduction of cost, and design freedom to scale custom system around the shelter module system and aesthetics.

The main design objectives driving the custom roof racking system are as follows:

(i) Manufacturability—minimal machining required

The custom racking system requires the aluminum U-channels to be cut to length and drilled for 4 Ø0.25” through holes.

(ii) Accessibility of Materials—standard construction stock and hardware

The principal building materials consist of 0.25” X 1.00 X 3.00 standard architectural 6063 aluminum U-channels for flexible sourcing.

(iii) Assembly and Serviceability—access to panels for installation and maintenance

Each individual panel is independently accessible for convenient maintenance in the necessity or replacement or repair.

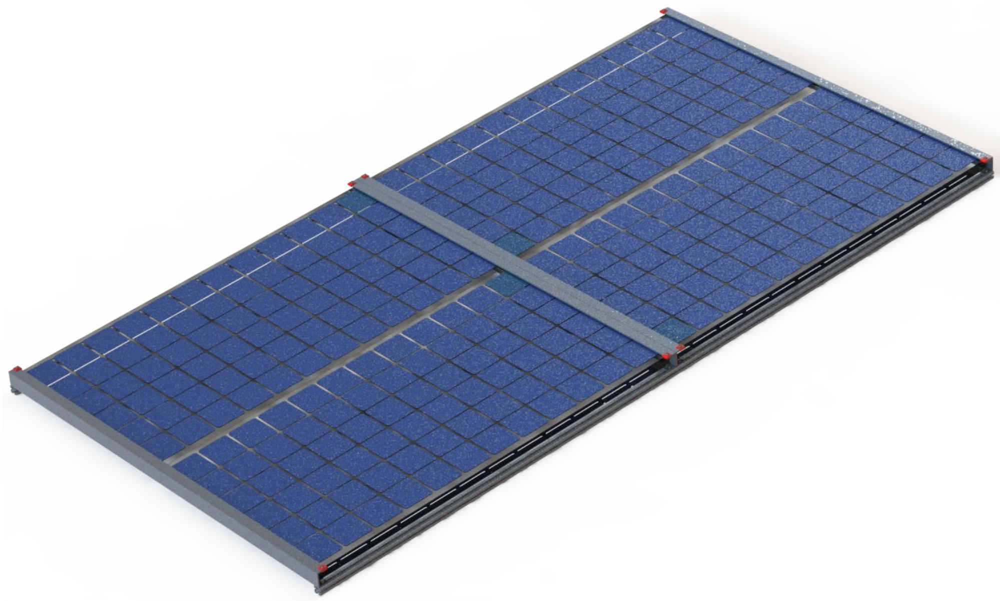


Figure 4: Solar Panel Roof Racking Assembly

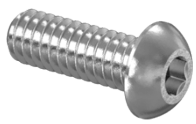
Recent design changes to the roof racking system this semester took place to ensure that the panels would still qualify for coverage under Lumos' warranty. Weather-resistant EPDM square gaskets with a 60A durometer were implemented to protect the glass panel from scratching and cracking at the interface with the 6063 Aluminum U-channel.

Side Panel Frame Plans

The two sets of 6061 Aluminium bars (for length and width) for the side panel framing will be machined using a common procedure. Machining will involve three main steps:

1) Cutting the bars to the right dimensions with an allowance of 0.05'' using a band saw machine (fine-cut using a mill machine)
2) Shaving out a profile from the bars to create the desired cross section using a mill machine
3) Drilling 0.20'' (7-20 drill bit) holes on the bars and threading them to 0.25'' to allow for fitting hex drive rounded head screws

Rounded head hex screw (stainless steel) pictured below will be used to hold the frame pieces together and the polycarbonate panel to the frame assembly.



Concrete Slab Pouring Plans

We decided how to set up our concrete slab last semester and our plan hasn't changed:

"As indicated in section 324-49 of the Ithaca, NY building code (TR.38-40) the concrete pad will be marked into separate rectangular slabs no more than 6' on a side by a cut that is 1.5" deep (¼ of the overall depth of the slab per industry best practices). Surface edges of each slab will be rounded to a radius of ¼". The forms for the concrete will be placed so that it slopes towards the road at ¼" per foot of width as described in TR.27. Per OR. 28-33, the City Engineer will provide approval for the line and grade of the pad as proposed and application for the survey will be made at the Engineer's office 24 hours before the slab is poured. If it is desired to pour the slab between October 1 and May 1, the appropriate permits will also be requested from the City Engineer. Where shelter pads are made adjacent to sidewalk curbs, a 1" expansion joint will be placed between the pad and curb and where they are adjacent to a building a ½" expansion joint will be placed between the pad and the build.

Using the code regulations, a 12' x 12' concrete slab with markings at 6' vertically and horizontally as shown in Figure 3 is proposed for a medium shelter module. This design allows the shelter to be placed towards the back of the concrete pad which provides just over a 4' deep pad area for bus stop patrons to use in front of the shelter. This area allows comfortable access to the side rail and a large space for standing with bicycles, large luggage, or animals that may be more difficult to have inside the shelter. The width of the concrete pad segments relative to the shelter modules also provides suitable support for the mounting of the shelter.

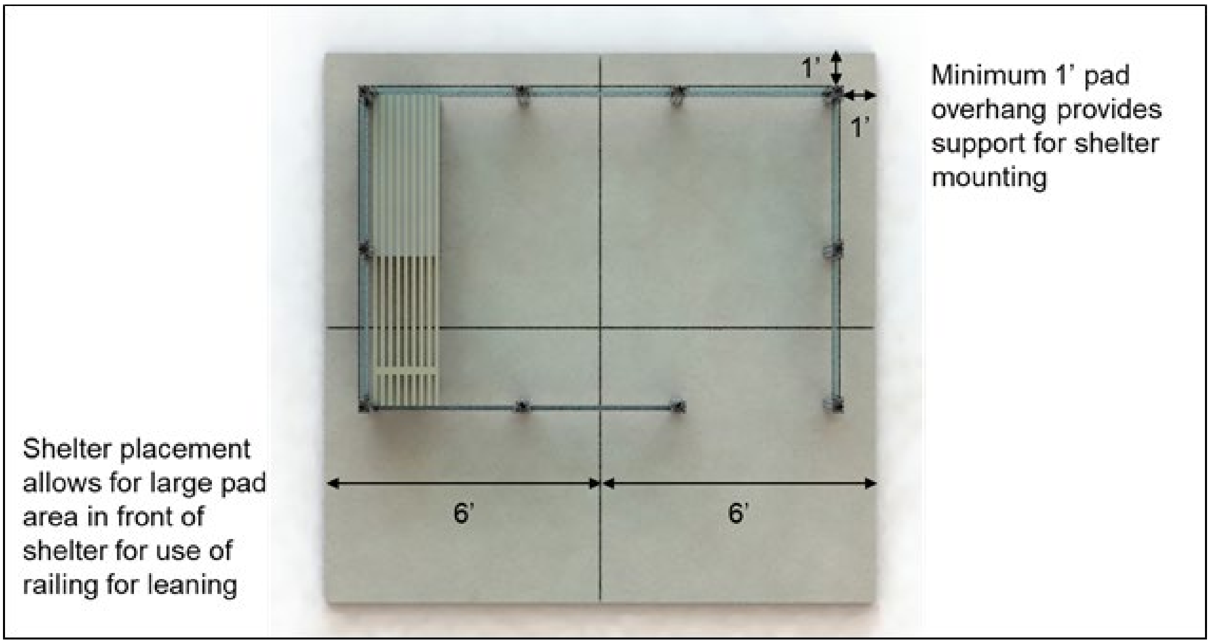


Figure 5: Concrete Pad Expansion and Shelter Placement

Structural Mounting Scheme

After analyzing the use cases and loads in Table R5 and discussing with the Taitem engineers, it was found that sufficient structural support for the shelter could be provided by ¾" stainless steel anchor bolts and using surface mounted brackets to support the vertical uprights for the frame of the shelter. This method is much less invasive than the previously proposed sonotube foundation and allows shelters to be installed on already existing concrete pad locations. Several types of anchor bolts and mechanisms shown in Figure 4 were considered.

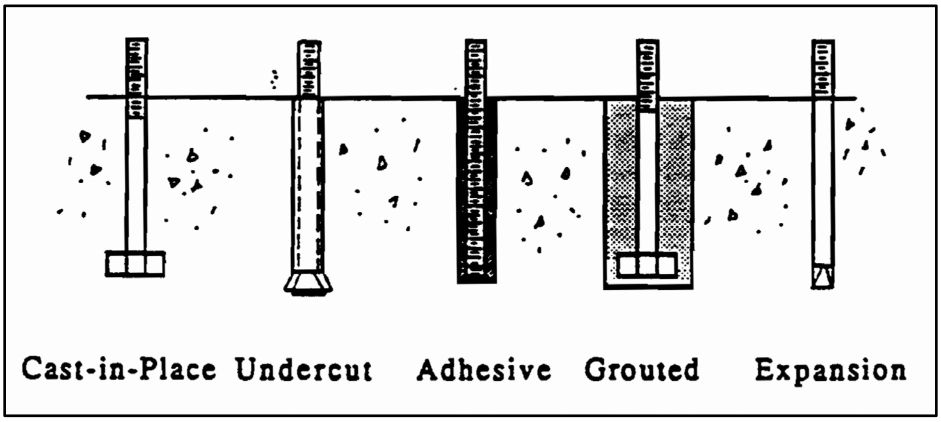
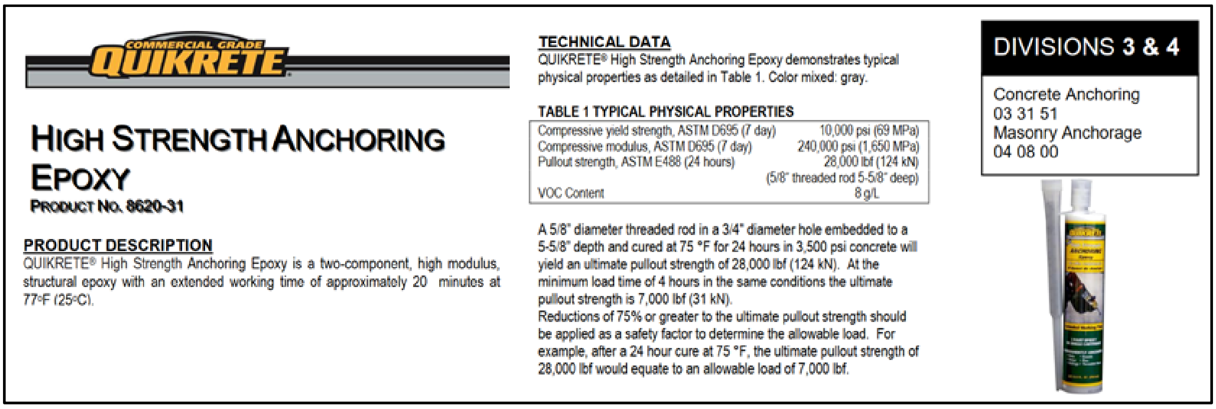


Figure 6: Anchor Bolt/Mechanism Types

Adhesive and expansion anchors were the two primary candidates evaluated as they both provide a relatively simple method for installing anchors on existing concrete pads. While each method has its pros/cons, adhesive anchors were ultimately selected because of the additional environmental resistance they provide in preventing moisture from entering the slab after installation and the additional structural support the epoxy provides for older concrete slabs that may have internal cracks and defects. If shelters are installed as part of new pad installations, cast-in-place anchors would be the preferred method. To ensure sufficient engagement depth of the anchor bolts without compromising the structural integrity of the concrete pad, 4” long anchor bolts were selected for the design. Per best practices from the anchoring epoxy manufacturer, the hole should be drilled ¼” larger than the threaded rod to be anchored to a depth that is at least 4.5 times the diameter of the bolt. Using a ¾” diameter rod, would imply that the hole needs to be 1” in diameter and 3 ⅜” deep.


COMMERCIAL GRADE QUIKRETE

HIGH STRENGTH ANCHORING EPOXY

PRODUCT NO. 8620-31

PRODUCT DESCRIPTION

QUIKRETE® High Strength Anchoring Epoxy is a two-component, high modulus, structural epoxy with an extended working time of approximately 20 minutes at 77°F (25°C).

TECHNICAL DATA

QUIKRETE® High Strength Anchoring Epoxy demonstrates typical physical properties as detailed in Table 1. Color mixed: gray.

TABLE 1 TYPICAL PHYSICAL PROPERTIES

Compressive yield strength, ASTM D695 (7 day)	10,000 psi (69 MPa)
Compressive modulus, ASTM D695 (7 day)	240,000 psi (1,650 MPa)
Pullout strength, ASTM E488 (24 hours)	28,000 lbf (124 kN) (5/8" threaded rod 5-5/8" deep)
VOC Content	8 g/L

A 5/8" diameter threaded rod in a 3/4" diameter hole embedded to a 5-5/8" depth and cured at 75 °F for 24 hours in 3,500 psi concrete will yield an ultimate pullout strength of 28,000 lbf (124 kN). At the minimum load time of 4 hours in the same conditions the ultimate pullout strength is 7,000 lbf (31 kN).
Reductions of 75% or greater to the ultimate pullout strength should be applied as a safety factor to determine the allowable load. For example, after a 24 hour cure at 75 °F, the ultimate pullout strength of 28,000 lbf would equate to an allowable load of 7,000 lbf.

DIVISIONS 3 & 4

Concrete Anchoring
03 31 51
Masonry Anchorage
04 08 00

Figure 7: Quikrete High Strength Anchoring Epoxy

A search of available adhesive products was performed and Quikrete High Strength Anchoring Epoxy with a pullout strength of 28,000 lbf, 10,000 psi, and a 20 minute working time was selected for use in the design. This selected product provides approximately a three hour cure time which should allow all anchor bolts for the shelter to be installed within the working time.

A number of different surface mounted brackets were evaluated to support the vertical uprights of the shelter. To address TR.1, DR.17, and OR.4-5, several aluminum and stainless steel mounting brackets with slotted mounting holes to allow for horizontal and vertical adjustment were considered. Considered styles of mounting bracket are shown in Figures 6-8 below.

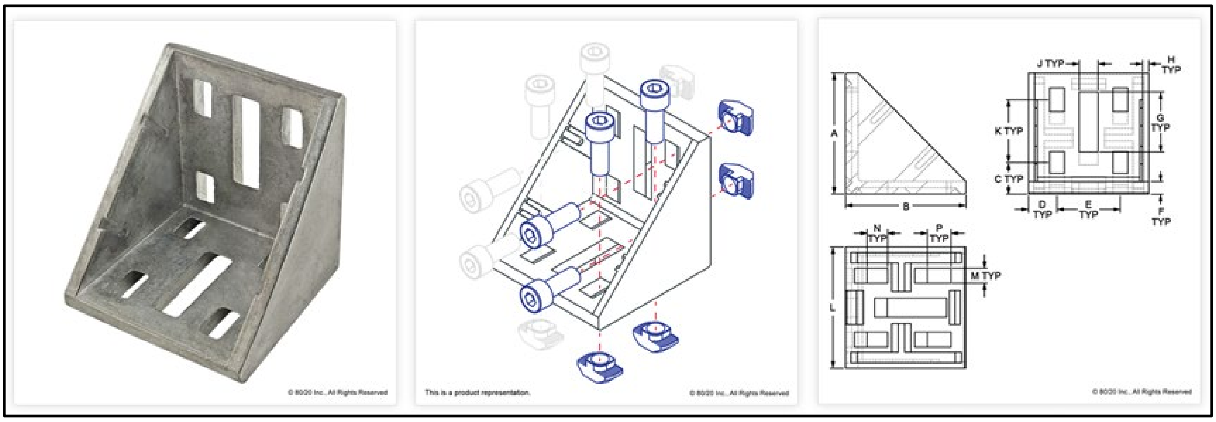


Figure 8: 80/20 Floor Mount Bracket P/N 14095

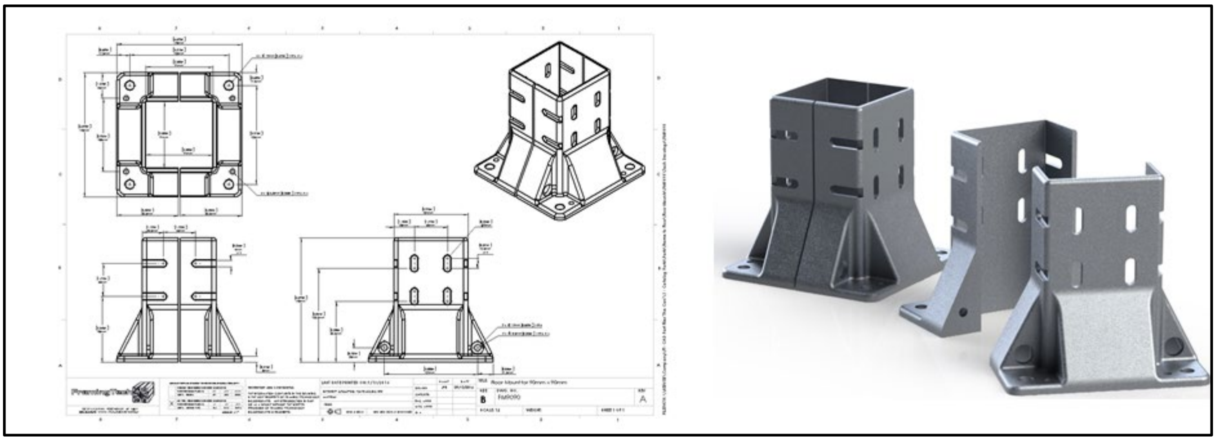


Figure 9: Framing Tech Floor Mount Base P/N FM9090

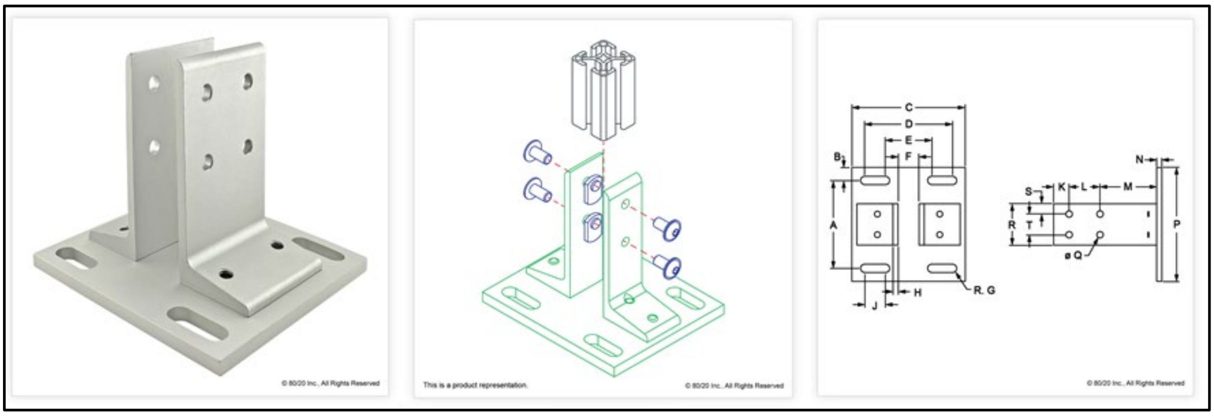


Figure 10: 80/20 15 Series Floor Mount Base P/N 2400

Based on its compatibility with the 80/20 extrusions, its structural support, and its ability to support adjustments in both horizontal and vertical mount points the 15 series floor mount base P/N 2400 from 80/20 was selected for the design. To accommodate the ¾” stainless anchor bolts, a thicker custom base plate will be fabricated with larger slots. To address DR.3 and DR.4, the vertical uprights must be connected to the base plate using a minimum of 2 stainless steel bolts, nuts, flat washers, and ¼” lock washers with tamper-resistant hardware. 80/20 manufactures P/N 3325 (5/16-18 x 0.750” black slide-in flange studs with washer and hex nut) and

P/N 3320 (5/16-18x0.687” flanged button head socket cap screw with slide-in t-nut) as shown in Figures 9-12 which are compatible with the selected P/N 2400 bracket. 5/16-18 slide-in flange studs, screws, and lock washers are available in stainless steel (to improve environmental resistance) and should be ordered with star or torx bit heads to ensure tamper resistance of the shelter mounting. Similarly, 4” long ¾” diameter stainless steel anchor bolts and grooved nuts should be use to ensure tamper and environmental resistance of the mounting of the bracket to the concrete pad.”

3325 is comprised of:

Part Number	Description	Qty
3116	5/16-18 x .750" Slide-In Flanged Economy T-Slot Stud	1
3214	5/16-18 Hex Nut	1
3260	.349" ID Washer	1

Figure 11: 80/20 Part Number 3325: 5/16-18 Slide-In Flanged T-Slot Stud, Hex Nut, and Washer

3320 is comprised of:

Part Number	Description	Qty
3330	5/16-18 x .687" Flanged Button Head Socket Cap Screw (FBHSCS)	1
3278	5/16-18 Slide-in Economy T-Nut - Offset Thread	1

Figure 12: 80/20 Part Number 3320: 5/16-18 Flanged Button Head Socket Cap Screw and T-Nut

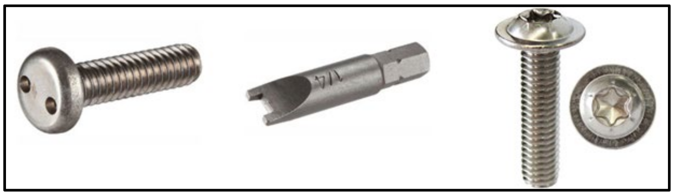


Figure 13: Stainless Steel Tamper-Resistant Screws and Driver

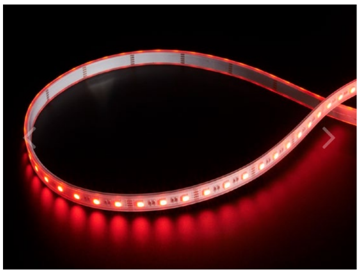
Figure 14: Stainless Steel Tamper-Resistant Grooved Nuts and Driver

LED Lights

This semester we focused on getting a strip of Led lights and testing it's operation with our bus location app. We purchased 1 reel (4 meters) of Analog RGBW LED Strip light from adafruit. We chose to go with an adafruit product so as to easily rely on the Raspberry Pi to control it. These are the specifications of Led strip:

- Width of Strip: 14mm / 0.55''
- Thickness of Strip: 4mm /0.2"
- 60 LEDs per meter
- Pixel Pitch: 16mm / 0.6"
- Single LED: 5mm * 5mm / 0.2" * 0.2"

The Led strip would obtain its power from our 12V battery and it's on and off switching would be facilitated by the Raspberry Pi. Using a python written script we would be able to send PWM signals to the RGB inputs of the Led strip and using different combinations for the RGB inputs we would be able to emit any suiting color in a patterned fashion. Below are some pictures of how different colors on the Led strip lights would appear.



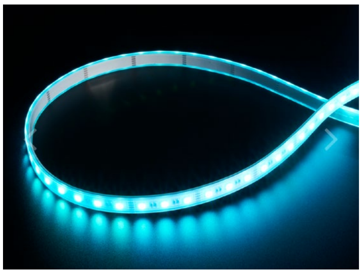
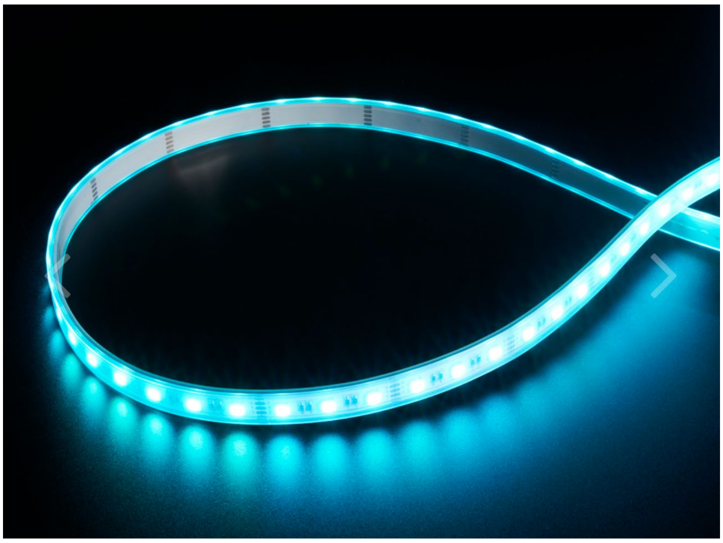


Figure 15: Analog RGBW LED Strip light from adafruit displaying different colors

The LED strip lights are weatherproof but we still chose to house them inside Led channels for added protection. We stuck with Muzata LED Aluminium Channel we chose last semester (Spring 2019) because it comes with a light diffuser which would soften and spread the concentrated light from the Led bulbs. Below is a close look at the channel and when the product is being used (images courtesy of Amazon).



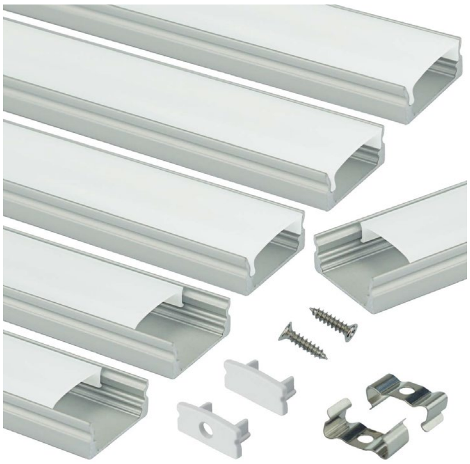


Figure 16: Aluminium Led housing image and its appearance when in use

Light Bar Conduit

The light bar conduit is a triangular sheet metal enclosure that serves the purpose of housing the upper wiring harness, mounting interior lighting and facilitating integration of electronic components located on the roof and shelter walls. The light bar conduit is mounted to the rear upper corner of the shelter.

Originally the conduit was implemented as a measure to allow the 10AWG solar panel wires to route to the roof-mounted solar panels discreetly, as the 3 in. bend radius of the wires is too large to route within the perpendicular junctions of the T-slot members. The functionality of the conduit was extended to serve as a modular plug-in unit to house interior lighting fixtures, motion sensors, and the wiring harness to connect the solar panels, LCD display, and hand crank to the shelter lower circuit that is located within the bench.

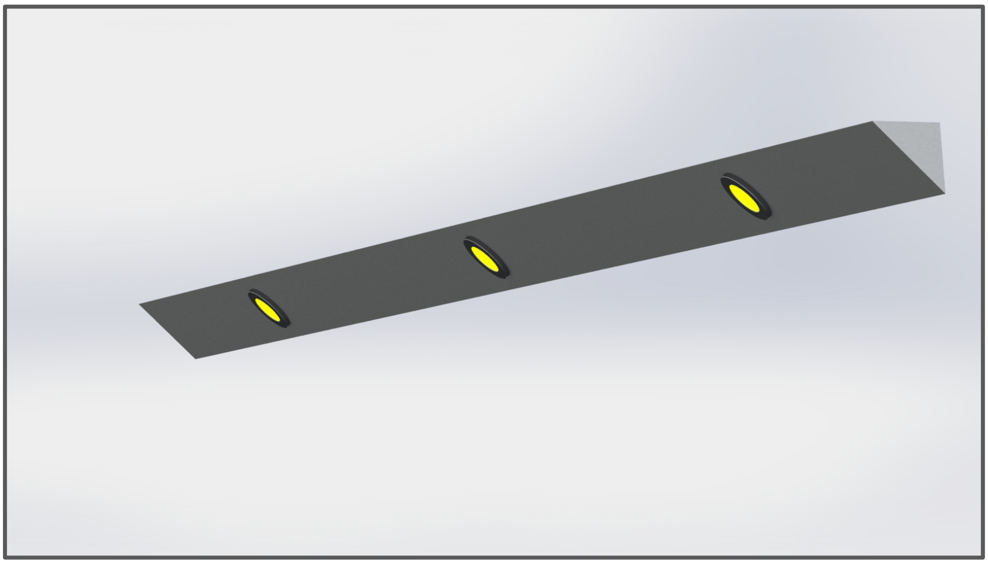


Figure 17: Light Bar Conduit CAD Model

The conduit itself is constructed from 0.063” thick aluminum sheet metal for its low cost properties, low weight, and widespread availability. The entire conduit enclosure is sealed under the assumption that it is welded; however, a structural adhesive could be used in the seams instead to decrease manufacturing cost. The conduit contains a sealed (using weatherproof foam gasket, captive stainless steel bolts, and countersunk stainless 10-32 bolts) backing access plate in the case that the internal wiring harness or motion sensor becomes damaged and needs servicing.

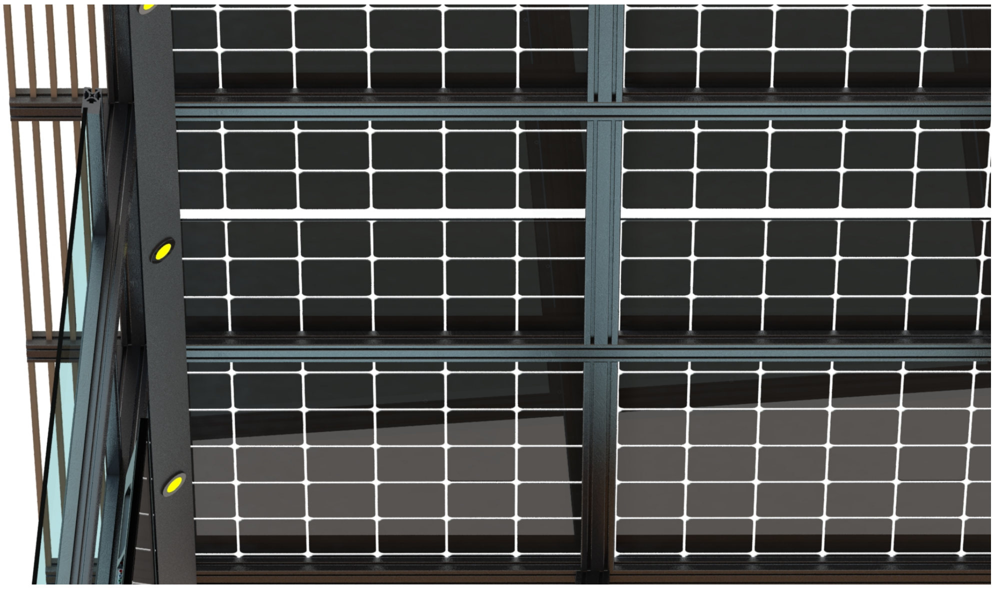


Figure 18: Interior View of Shelter with Light Bar Conduit

In order to ensure the modularity of the conduit as a component, wall mount connectors will be used at all wire interfaces with the conduit. This feature allows for the conduit to be assembled onto the shelter and then simply plugged into the shelter circuit without opening the housing and snaking or splicing wires that run throughout the main vertical support beams of the shelter. The selected wall mount connectors must be waterproof and relatively slim in profile to prevent damages during handling of the conduit. Two wall mount connectors were selected with an IP67 waterproof rating (typically containing a gaset, wire seal, and female connector cover) to satisfy resistance to rain and snow conditions and prevent water from entering through the cables and pooling in the sealed conduit. Two styles of waterproof wall mount connectors were selected for the conduit including a 12-pin aviation connector for the central wiring harness connecting the conduit to the bench, and 2-pin Deutsch connectors for each solar panel, the LCD display, and the hand crank. All connectors will be mounted to the top face of the conduit to allow for additional room to properly route cables while ensuring the cables are hidden. In total, the conduit will have one 12-pin connector mounted on the top face of the conduit nearest to the bench, one Deutsch connector for the LCD display, and a Deutsch connector for each solar panel of the roof.

Figure 19: Selected Wall Mount Connectors for Conduit

The lighting selection for the conduit consists of 12V LED RV/boat interior lights. These lights were selected because they are waterproof, low power consumption, and have recessed mounting but are still slim enough to allow for ample room for packaging wires and any additional components in the conduit. Additionally, the round aluminum trim seemed consistent with the aesthetic styling of the shelter, and the slightly warm tone (3000K) of the light beam produces an inviting environment for those occupying the shelter.

Although the lights come with a specification of 240 lumens and a beam angle of 120 degrees, we were initially unsure of the approximate number of lights necessary to create a bright enough environment for the shelter occupant. After testing the lights at 12V, we found that 2 lights per module seemed to produce ample light for shelter occupation, and 1 light continuously on will suffice to illuminate the entire shelter when it is not occupied. Additionally, a polycarbonate or resin cover could be placed over the lit face of the conduit to allow for further light dispersion and customization of lighting tint color. It would be useful to conduct an analysis with lighting software to analytically determine if the lighting configuration meets industry standards for lighting levels appropriate for typical user behavior in the shelter. This type of analysis would also facilitate selecting the optimal mounting height and angle of the conduit within the shelter.

Figure 20: Selected Interior Lights for Conduit

The triangular conduit will be mounted using 5/16-18 tamper proof bolts and T-slot mounting nuts to allow for ease of installation and mounting uniformity with other shelter features such as the panels, hand crank, and shelter frame foundation hardware.

This semester we began the first prototype of a single module triangular conduit. The objectives of this prototype are as follows:

a. Test number, position, and angle of lights for various use cases of shelter
b. Facilitate full prototype mock up of electronics mounted in their representative positions in the shelter
c. Test assembly and serviceability of the light bar conduit system

Figure 21: Fabrication of Single Module Light Bar Conduit Prototype

Bench Design

The bench system is the housing for the shelter's primary electronic components, excluding UI features such as the LED lights and the TV. According to the design, the bench enclosure currently includes the solar charge controller, DC-AC inverter, the raspberry pi, and the on-board battery. Since the bench system is housing most of the electronics, it is vital to ensure the functionality and safety of the components inside. This semester, the team primarily focused on the range of operating temperatures of all the components housed inside, and how the bench can maintain this temperature range during the fluctuation of temperature in Ithaca. This was a consideration that had not been previously addressed, albeit a very important one.

Once specifications and models for all components were finalized, the operating temperature ranges of each one were compiled from datasheets and compared to local temperature data.

Componen	Min. Operating	Max. Operating

t	Temp (°C)	Temp (°C)
Battery	-10	60
Charge Controller	-20	45
Raspberry Pi	0	50
Inverter	-20	40

Figure 22: Operating Temperature Ranges of Major Components

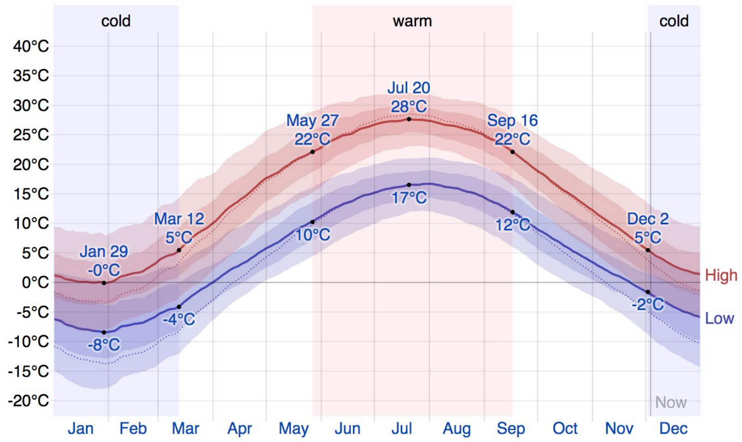


Figure 23: Average High and Low Temperature in Ithaca, NY; 2018-2019

The Raspberry Pi failing below freezing was certainly going to be a problem. According to Figure 21, the Pi would be inoperable for at least four months of the year, and revealed that particularly cold days might ultimately kill the battery. Batteries in general are very susceptible to temperature, with the charge rate and storage capacity decreasing exponentially with temperature below optimal.

Another number stood out - the inverter failing at 40°C / 104°F. With extremely hot days reaching 35°C / 95°F, we wanted to know if the additional heat generated by surrounding electronics could fry the inverter. Using specifications from datasheets and assumptions regarding charging loss and bench dimensions, we determined the heat capacity of the enclosure.

Battery: 12W*100Ah = 1200Wh
Cycle use: 14.9V*30A = 447W
Efficiency: 85% (assumed for sulfuric acid batteries) at storing

Standby Use: 13.8V*30A = 414W
Charging Loss: 447W*15% = 67.05W (J/s)
Maximum Charging Loss: 447W*40% = 178..8W (J/s)

Internal Resistance: 5mΩ
Maximum Heat Generated due to resistance: 30A^2*5mΩ = 45W

Enclosure size: 500*400*200 = 4*10^7 mm^3 = 0.04 m^3
Battery size: 12.17in * 6.61in * 8.30in = 667.68 in^3 = 0.01m^3

Cv for Air = 0.718 (at 300k) kJ/kg*k Air density = 1.225 kg/m^3
Air weight= 1.225 kg/m^3 * (0.04-0.01)m^3 = 0.03675kg

Air Heat Capacity: 0.718*0.03675*300 = 7.916kJ = 791.6J

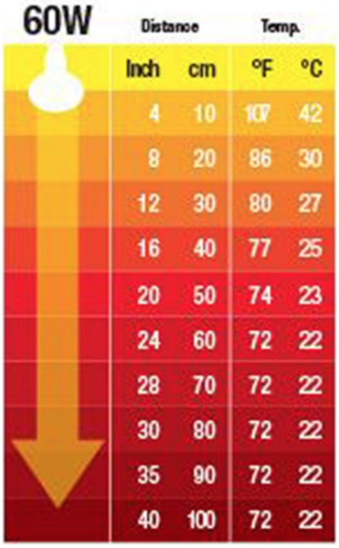
Figure 24: Calculation of Heat Capacity of Air inside Enclosure

The order of magnitude of our answer tells us that the heat produced by the battery will most likely not contribute to a large increase in ambient temperature. However, the Charge Controller and Inverter are estimated to produce more heat, and thus empirical data would be required to make a conclusion. This led us to determine that the bench **needs to be heated** during the winter, and **potentially needs cooling** during the summer, and begin building a prototype.

For the solution to resolve the effect of temperature fluctuation, the team proposed two solutions for two different conditions:

Winter

Firstly, the bench would be insulated. This would trap any heat generated by our electronics by reducing heat transfer to outside. But given that cold temperatures pose a substantial threat to the operation, efficiency, and life expectancy of our system, we wanted an active heat source in addition to a passive solution. This led us to find a 60 Watt ceramic bulb that emits heat to raise the enclosure's ambient temperature. Using the Raspberry Pi and a temperature sensor, we can communicate with the outlet relay and give power to the bulb when the temperature falls below a desirable threshold.


60W

Distance		Temp.	
Inch	cm	°F	°C
4	10	107	42
8	20	86	30
12	30	80	27
16	40	77	25
20	50	74	23
24	60	72	22
28	70	72	22
30	80	72	22
35	90	72	22
40	100	72	22

Figure 25: Temperature vs Distance at Maximum Power

A consideration for the design and layout is that the bulb could potentially fry our electronics if we placed it to close. Figure 23 indicates a minimum distance of 8 inches between the heat source and our most heat sensitive component (the Inverter), and ideally as close to the most cold sensitive component (the Pi). The threshold temperature which activates the bulb would be determined by the rate at which the bulb is able to heat up; the longer it takes, the higher we would want our threshold to be.

Summer

This solution is proposed for the situation in summer temperatures where the housing will be heated up due to components' heat dissipation and atmospheric conditions outside of the housing. Giving the internal resistance of the components and the temperature fluctuations during summers, there is a potential risk of overheating the components during summers.

This design is for ventilating the heat generated in the bench housing, the design will include a heat sink on one side of the housing and an active cooling fan to increase the flow of air within the fins of the heatsink. The concept is shown below:

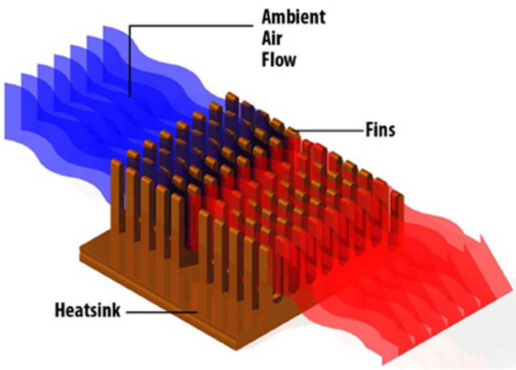


Figure 26: Basic Schematic of Heat Sink

The heatsink will be covered by insulation at 2 of its sides and the top to prevent necessary heat loss during winters, the front and back side will be left open to allow the connection with the cooling fan and the flow of air during operation.

The cooling system will be connected to and powered by the charge control. The charge control will be able to turn the cooling system on and off based on its temperature sensor's reading, therefore no excessive cooling will be applied and save energy from the overall shelter system.

With the lack of time from this semester and opportunity to test the heating profile of the components in a warm environment, the team proposed this conceptual solution during the design phase, with the associated proofs of concept planned for next semester.

Currently all parts have been ordered, our next step is to build an insulated enclosure, wire together the major components, draw power from the battery, and take temperature measurements.

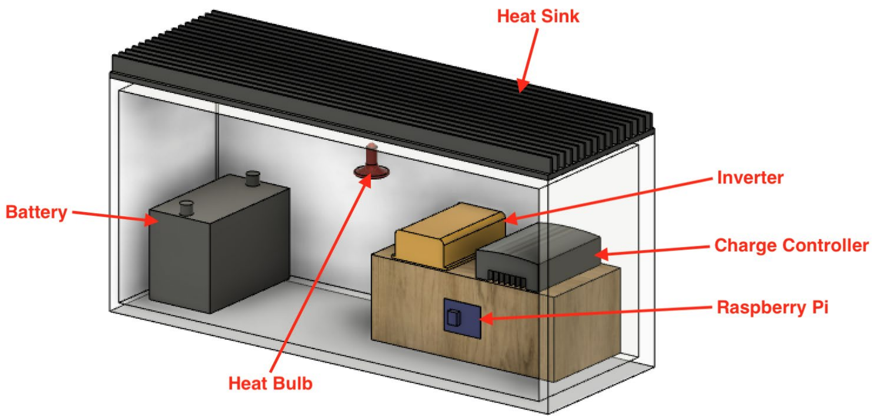


Figure 27: CAD of Bench Prototype

Burning the insulation is something we want to avoid. Therefore the heating bulb will hang a couple inches from the roof. The inverter, charge controller, and Pi will be mounted on a block of wood. The bench (equipment housing) will be tested during a cold day of the winter to record the temperature fluctuation inside the housing with/without the heating system. Associated heat generated by the electrical components inside the housing and the energy used by the heating system will also be recorded to estimate the cost of energy. The cooling system will be prototyped after the design of the heating system. The team will test the cooling efficiency of the system in a warm environment to determine if the system is sufficient to cool the housing during summer. Adjustment of the design will be added accordingly after the test.

Electrical Breakdown

Overview

This semester, all the segments of the electrical system of the bus shelter were tested individually and integrated into a single system. The system functions with a Raspberry Pi as the main computer. The various segments of this system are as follows:

- Collect data from the Renogy Rover solar charge controller about solar power, battery consumption, etc.
- Display real-time information about incoming buses on an LCD screen in the shelter
- Control the lights inside the shelter depending on activity computed based on input from a motion sensor
- Indicator lights outside the shelter that glow depending on time before the next bus arrives

Solar Data Collection

After a thorough investigation of various solar charge controllers last year, we finalized the Renogy Rover Li 40A MPPT Charge Controller. It is an MPPT (Maximum Power Point Tracking) controller that minimizes wasted solar energy as power is transferred through the unit. The controller connects easily to the Raspberry Pi and communicates using the RS-232 protocol. We used the Solarshed Python library (https://github.com/corbinbs/solarshed) to establish a connection with the charge controller and obtain information about important factors about the solar power system like charging status, load power, solar power, solar current, battery voltage, etc.

Renogy Rover Li 40A Charge Controller

All the data obtained from the charge controller is temporarily stored in the Raspberry Pi storage in a text file in the form of a JSON string. The structure of this JSON string is as follows:


```
{
  “time”: “12-05-19 17:25”
  “charging_status”: 0.8,
  “load_power”: 34,
```

```
  “solar_power”: 50,
  “power_today” : 16
}
```


This text file is used by the Javascript program running on the Raspberry Pi for the information display as described in the next section. In the future, this data can be stored on a cloud database for reference and analysis.

Data Display and UX

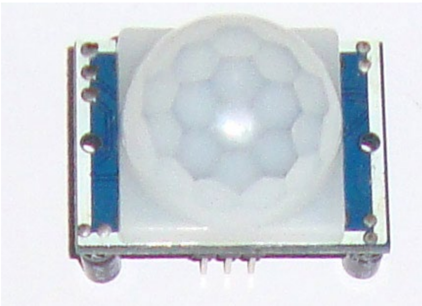
The raspberry pi hosts the website where our bus stop information will be displayed. This website includes information as lined out in our UX planning phase. Time of arrival, bus route number, and proceeding stops are the main elements of our main page. In addition to the bus route page, we have a second page displaying the battery usage and efficiency statistics of the bus shelter as a whole. This data is reported by the charge controller, transferred to the raspberry pi and stored as a json file. From there, the website reads this constantly updated json file to provide real-time updates and show the statistics on the secondary display screen.

The current goals for enhancing the website are implementing the json reading script that the website will run every minute to update the efficiency statistics. This requires learning javascript enough to be able to place this script into the hierarchy of the website’s structure, and being able to read the json file correctly. This process will be fully implemented as soon as the other portion of the team is able to fashion the data into a json file from the charge controller. In addition to being able to access this data on the locally hosted website, more work is going into the UX elements of the main display screen. The information concerning the proceeding stops of every bus route is already gathered, CSS has to be utilized to have the right-hand panel displaying this information line up with the impending bus (the one with the lowest amount of minutes until arrival). The basic CSS is there, it just needs refining and some logic referential to the current bus route.

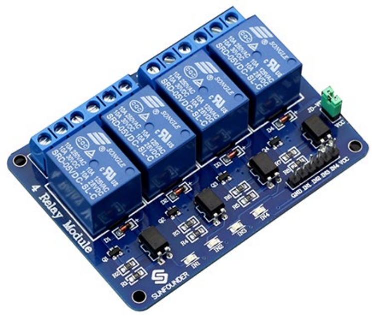
We have all the data we could possibly need from TCAT, as we send HTTP requests to the TCAT API to retrieve all relevant bus stop data. The website correctly displays this information, and updates constantly to correctly represent the amount of time for the buses to arrive. We will be implementing a shift to the second display screen to show efficiency statistics of the bus shelter on a timer as well. This addition and shift will allow the webpage to display crucial bus route information as well as energy and efficiency related statistics for anyone using our bus shelter.

Efficient Power Control

In order to manage power consumption in the shelter so that the solar power generated sufficiently accounts for all the energy consumed, we implemented a smart power control. This system ensures that the electrical components of the shelter like the LCD display and overhead lights are turned off when the shelter has been inactive for a long time. This was done using a PIR (Passive InfraRed) Motion Sensor which simply detects whether a human has moved in or out of its range. We decided on using the HC-SR501 sensor module which is easy to set up with a Raspberry Pi. When the sensor doesn't detect any movement in its range for a long time, the system turns off the lights inside the shelter and puts the LCD display on standby until the sensor detects any motion again. The lights are controlled using a relay module in which the 5V relays are operated by the Raspberry Pi, which disconnects the lights from the power supply when required. The Pi also sends an internal standby signal to the LCD display to turn it off.



HC-SR501 PIR Motion Sensor

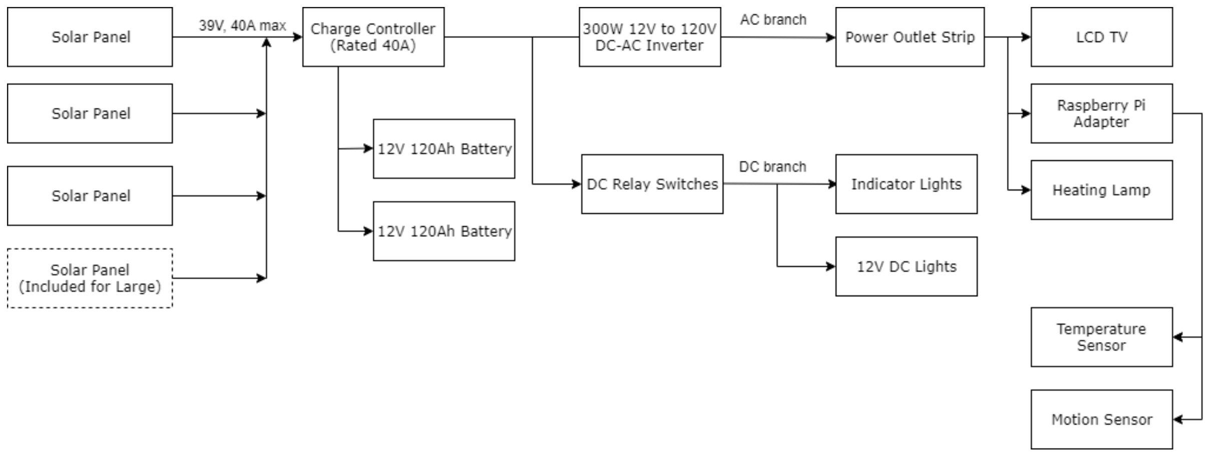


4-Relay 5V module

Indicator Lights - Augie

In addition to the real-time information displayed in our LCD screens, we have also added LED indicator lights, to notify TCAT riders (typically standing away from the shelter) that a bus is soon arriving. When a bus is two minutes away from arrival, the indicator lights will turn on, letting bystanders know that a bus is approaching. Whether a rider is standing at or a couple of feet away from the bus stop, the riders become aware that it's time to approach the stop and make sure they catch their ride. For instance, during cold winters and hot summers, riders waiting for a bus tend to stay inside an enclosed building (e.g. Starbucks coffee shop) for protection against extreme weather. However, there are various problems. Riders may not have access to the bus-tracking mobile app, or may not be able to see buses approaching due to obstructions from within buildings. Although the LCD Screens are fantastic features in informing the riders of the next bus' exact arrival time, it requires the rider to be standing at the bus stop in the cold. Fortunately, the indicator lights can help to resolve such problems.

Circuit Description



Functional block diagram of the electrical setup

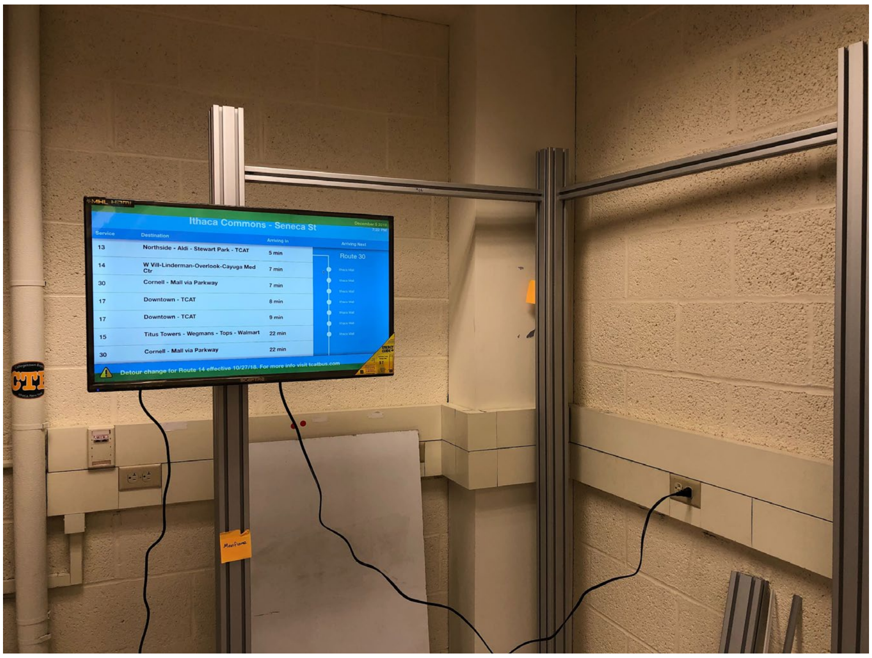
All the electrical components in the shelter are connected to each other by the following functional block diagram. The individual solar panels are rated for a maximum of 39V and 10A and will be connected in parallel. The wiring of each panel in parallel will make the system more robust if a panel happens to malfunction and stop working. The charge controller is then the joining device between the solar panels, batteries, and loads. The charge controller will serve as the hub for monitoring charge distribution and data collection of the working system. Two 12V, 120Ah batteries will be utilized in order to have sufficient storage capabilities.

In terms of loads, there will need to be both an AC and DC power supply line for the components considered in the design. The AC power supply will be provided by a 300W 12V DC to 120V AC inverter that will be responsible for operating the LCD television, 5V Raspberry Pi power adapter, and heating lamp for the bench compartment. From the Raspberry Pi, wires will be utilized to control the DC power switching relay, temperature sensor, and motion detector to implement energy saving techniques when the shelter is not in use or reaches low temperature levels.

A 12V DC branch will be required to power the LED indicator lights and the 12V RV lights used for the shelter main lighting. A 12V relay switching unit will be controlled by the Raspberry Pi to dictate when the lights turn on, off, dim, or change color.

Prototyping

This semester, our main goal was to create a prototype of our current design of the shelter as a proof of concept, as well as a method of discovering potential design considerations and changes for the implementable version. We decided to prototype only a corner of the shelter, with as many of the features of the final shelter as possible. The purpose of this was to see if our design was feasible, as well as to try to uncover any aspects of the design that we might have overlooked. We prototyped a corner of the shelter, with all of the electronic components including the TV, Light Conduit, Indicator lights and the Motion Sensor. We are still in the process of putting everything together.



After prototyping this corner, we found a few design changes that will be considered in our next shelter iteration. Firstly we plan to implement deutsch connectors on the back of the conduit to easily connect the wiring harness to the conduit. On the top of the conduit we also plan to add MC4 connectors to comply with the standard for solar panels. The heart of all our wiring will remain the conduit and in the back left corner of the shelter to minimize the amount of work needed when first assembling the shelter.

We have also decided to scrap the removable panel mount to reduce costs and machining time. We are now looking at alternative options that are compatible with our 15 series T-slots. The most promising option is a t-nut L bracket which will make assembly and removal of panels easier and cheaper.

We also want to experiment with security hardware, and test the ease of assemble. Currently we are using round head allen keys, making it easier to install the double butt fasteners to the subfram members. We need to find the right security hardware that will allow for angled installation.

Master Plan Subteam

Introduction

Our Previous Work

In Spring 2019, the Master Plan team focused on data collection for bus stops and shelters on the Cornell University campus based on physical metrics such as shelter size and condition, and then providing that data to our main stakeholder, Tompkins Consolidated Area Transit, Inc. (TCAT) so they would have more useful data on the state of the shelters that their buses serve. Based on that data, the team created a prototype database spreadsheet to help make decisions. In this spreadsheet, stops were separated into two groups, those with shelters and those without. For stops with shelters, the prototype could be used to determine the shelters that needed to be replaced by new ones, the shelters that could be left as is, and the shelters that could be removed altogether. For stops without shelters, the prototype could be used to decide where new shelters should be built.

Fall 2019

Summary

This semester, we set out to expand on previous semesters' work. While the scope of the prototype spreadsheet was impressive, it did little to examine human-centered metrics that TCAT was interested in. In this vein, we decided to carry out our empathy fieldwork in a more human-centered manner based on selected bus stops with shelters on campus. This way, we could gain a deeper understanding of passengers' real needs in order to start mapping our overall design. We ultimately decided to focus on major bus shelters on Cornell University's Central, North and West campus, conducting detailed user experience research on each of them. We collected our emotional data and came up with the most prominent needs. In addition, we created a persona context diagram, and combined it with background information from the previous semester in order to give an all-around prototype for the future design process to happen.

Systems Tools

This semester, the Master Plan team split into fieldwork groups, each in charge of three to four shelters around the Cornell campus. The team focused on collecting data during rush hours, observing how bus users interacted with the environment when waiting for the bus and talking to bus users about their experiences with the current transit system. The data that the team collected during observations and conversations was used throughout the fieldwork process, from direct fieldwork all the way to the creation and fleshing out of user personas. After the personas were fleshed out, the team created systems tools to analyze the system. In particular, a context diagram was used to establish the relationship between the system and relevant stakeholders. The team also collected requirements based on empathy fieldwork outcomes and other necessary considerations that the stakeholders might need. Use cases and use case behavioral diagrams were created to understand user interactions with the system. Based on the collected information and the analysis by the previous system tools, the team created a HMW(How Might We) Capabilities Diagram and a Persona Context Diagram to further understand the stakeholders' requirements, so that future improvements can be made and the goals are clear.

Empathy Fieldwork

The team collected data on 16 bus stops around campus and came up with 30 sheets of empathy fieldwork. The following is a sample form, showing how the team gathered data through 1st, 2nd and 3rd person empathy experiences.

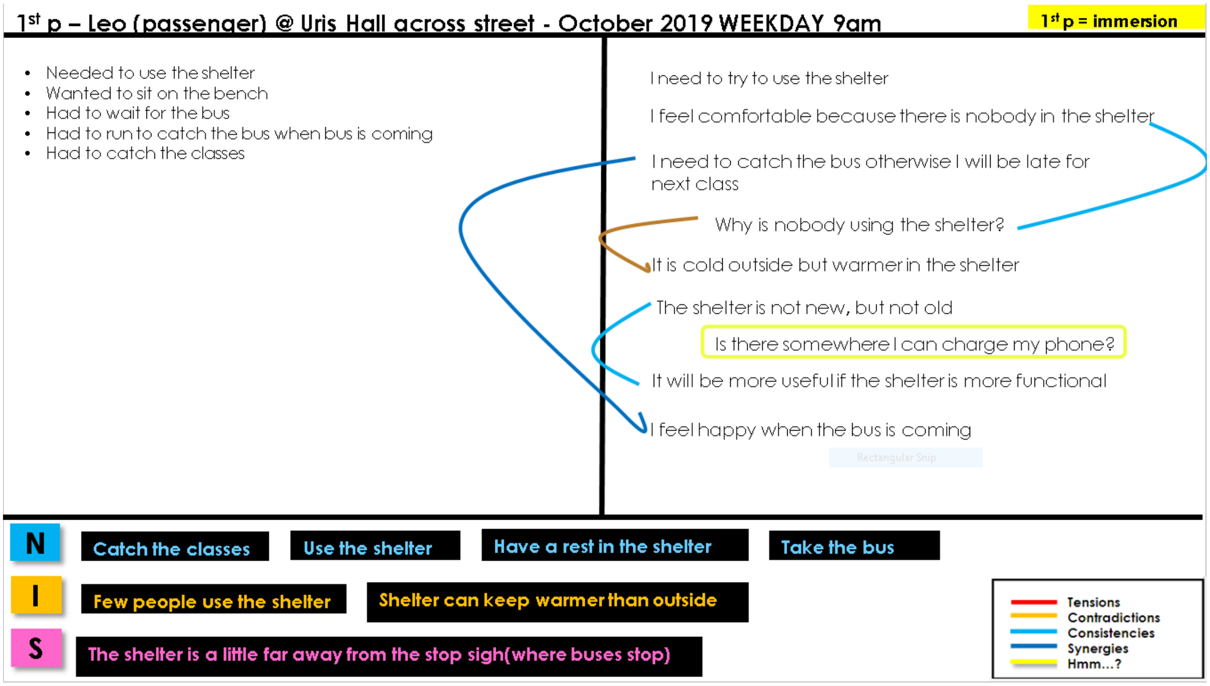
Immersion (1st person fieldwork) involves team members using the system first-hand, acting as students, faculty members and other possible users, in order to get subjective data related to how real users would experience the system.

Observation (3nd person fieldwork) entails observing campus bus shelters and how they interact with both the environment and users. This allows team members to get both a large-scale overview of how users, the environment, and the system itself (in this case, bus shelters) interact with each other and detailed findings not possible through the other two methods.

Finally, engagement (2nd person fieldwork) involves team members meeting directly with users in the actual setting and interviewing them with prepared questions. In particular, these questions center around their subjective feelings, allowing team members to get a deep understanding of the emotions surrounding the use of the system.

Empathy fieldwork is thus a comprehensive method enabling us to identify customer needs and the interplay between these needs and the existing system from a variety of angles.

During the unpacking process (which occurs after the fieldwork has concluded), the raw results are translated into *emotional data*, deeper insights into how users interact. This includes interesting patterns, as well as deeper questions about *why* users act and feel the way that they do.



Insights from emotional data

After combining all the emotional data, we grouped the data into categories that were further combined into larger groups. During this grouping process, heavier weighting was given to indicators with mentioned more often, which indicated a greater level of importance. It is clear that ‘convenience of use’ is considered the most critical factor in the system designed, followed by ‘busy life’ and ‘provide protection’. It is surprising to see that even if many shelters are in good condition, there are still a lot of people who are not willing to use them. It seems that there must be some problems related to the environment, the convenience of use and the amount of protection the shelters can provide. Further, we created 9 personas described with the keywords extracted from the emotional database, representing the users we are designing for.

Busy Life of Passengers	14%	Busy Life	14%
bad experience	1%	Design	4%
Bad Environment	2%		
Bad design	1%		
Good Surrounding	3%	Surrounding	3%
Good Conditions	3%	Facility Condition	8%
Poor Conditions	5%		
Make the shelter comfortable	7%	Ease of Use	19%
Capacity	5%		
make life easier	3%		
Make the shelter convenient	4%		
Safety	2%	Protection	13%
Protection	10%		
Protection from the cold	1%		
Timely	2%	Catch Buses	10%
A useful tracking system	7%		
inappropriate schedule	1%		
Overuse of Public Resources	3%	Public Resources	3%
future inspirations	1%	New Ideas	1%
Use Frequency	5%	Willingness to Use	12%
Willingness to use	7%		
Route Design	1%	Location	9%
Location	8%		

Personas

Tom is a **stressed out** junior studying mechanical engineering at Cornell University. He lives **far from campus**. His apartment is in Lansing, far north of campus, where he **lives alone**. He does have a car, but he **can't drive it in the snow**.

He is a **night owl** but unfortunately has morning classes this semester, which **frustrates** him as he doesn't know how to get to campus during snowy mornings.

The goal of the system is to provide a better planned **location of the bus stop/shelter**, would allow Tom to easily find and **feel comfortable** waiting there.

	**Ayesha** is a graduate student from California. She is studying accounting at Cornell University and she lives in downtown Ithaca. She **drives to school** if there is a meeting in the evening but **usually she takes the bus to campus**. She wakes up early and she usually gets to the bus stop 10 mins earlier than the scheduled arrival time. She enjoys waiting for buses with a cup of coffee and when it is not cold. The goal of the system is to provide a **better waiting experience**, including amenities such as warmers and seats, would be appreciated by Ayesha.
	**Andy** is a senior studying in ORIE at Cornell University. He only has 8 credits this semester so he doesn't come to campus very often. He doesn't have a car, so he has to **take the bus or walk to campus**. He sometimes has meetings and group work in the evening and they might be done late at night. He doesn't feel very **safe** taking buses or **waiting for buses** at the shelters alone. The goal of the system is to provide a better waiting experience and especially improved **safety equipment** would be appreciated by Alan.
	**Faisal** is a **passenger,** who usually uses the stop **Uris Hall across the street** to wait for and take the bus **between his classes and home**. He uses this stop **almost every weekday** because he always has classes nearby. He thinks **using the shelter is not necessary** because usually he does not need to wait for a long time and the shelter in this stop is **a little far away from the bus stop sign**. However, he thinks he would use the shelter **in bad weather**, like heavy rain, heavy wind and extreme cold. The goal of the system is to understand **how the passengers can use the shelter and how much they are satisfied** with the current stop and shelter design and to receive the suggestions to help us **improve the current services and increase the users' satisfaction level**.

	**Carol** is a **student** who usually uses the stop **Carpenter Hall** to take the bus **between her classes and home**. She uses this stop **almost every weekday**. She **hardly sits in the shelter** but stands inside sometimes, because she thinks the buses are always on time. However, when she **feels tired**, she would try to sit. She thinks this shelter is not large enough. The goal of the system is to understand **how the passengers can use the shelter and how much they are satisfied** with the current stop and shelter design and to receive the suggestions to help us **improve the current services and increase the users' satisfaction level**.
	**Vanessa** is a **student** who usually uses the stop **Carpenter Hall** to take the bus **between her classes and home**. She usually uses this stop **on Tuesday and Thursday** because she has classes nearby in these days. She **sometimes** uses the shelter by **sitting inside**. She thinks there is no delays for the buses she usually takes. She thinks the current design of the shelter is **good enough** to support her general use. The goal of the system is to understand **how the passengers can use the shelter and how much they are satisfied** with the current stop and shelter design. To receive the suggestions to help us **improve the current services and increase the users' satisfaction level**.
	**Rachel** is a **stressed out staff member at Cornell**, who is living far away off campus and comes home late really worn out. Even though she really enjoys the convenient TCAT bus system, she still has a very **hard time taking certain routes** and complains about **the inconvenience** to friends. The goal of the system is to provide a **bus shelter system** that gives her more **protection** during the winter and make her transit experience **enjoyable**.
	**Lydia** is a **hardworking student at Cornell,** who always stays at the library until midnight and takes the bus back home. She finds that taking the bus back home in the winter is extremely **warm and comfortable**, but the problem is that buses are often **late** at midnight. The goal of the system is to provide a bus shelter system that students can **enjoy** the time waiting for

	buses.
	**Hilary** is a Cornell postdoc in Biotech who often stays at the lab until midnight and feels **worn out** back home. She has to **walk to other areas** on campus during the day since most of the places are not that far nor close, but **buses are not that frequent**. Also, the shelter is extremely **crowded** during rush hours. The goal of the system is to provide a bus shelter system where she could go to other buildings more **conveniently**.

Fleshing out the Personas

	**Tom** **Age: 20** **Social Life:** He is a very social person and has a lot of friends who live nearby or on campus. Tom goes to a party almost every weekend. The parties are hosted at his friends' houses, most of which are in or near Collegetown. **Work Life:** It has been a relatively busy semester for him as a Junior at Cornell University. If he needs to stay on campus for a whole day, he tends to take the bus because parking is expensive. **Key Attributes:** •He loves to party •He has good grades •He likes to drive in good weather
	**Ayesha** **Age: 23** **Social Life:** She doesn't have much of a social life and she lives with her boyfriend. On the weekends, she might go hiking with her friends if weather permits. Other than that, she usually stays at home. **Work Life:** As a graduate student, she has tons of group work to do. The group work and meetings are usually in the nights so she needs to drive or take the bus to campus at night. **Key Attributes:** •Cheerful •Creative •She loves watching YouTube. •She doesn't like driving

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Alan

Age: 22

Social Life: He lives with four roommates and has many friends. He enjoys interacting with people and he is currently enrolled in 3 different student organizations, which makes him busy in meetings. He likes to stay at home on weekends and doesn't go out if there is no meetings or classes.

Work life: He only has 8 credits this semester so it is a relatively easy semester for him. However, since that he is enrolled in 3 different student organizations, he has to come to campus quite often in the evenings.

Key Attribute:
•He enjoys cooking at home
•He doesn't like to travel around
•He gets along well with his roommates

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Faisal

Age: 24

Work Life: He is passenger and uses Uris Hall across street bus stop almost every weekday to take the bus home from class. He thinks it is not necessary to use the shelter while waiting for the bus because he usually does not need to wait for a long time. However, he would use the shelter in bad weather.

Key Attributes:
•He thinks he does not need to use shelter
•He thinks the shelter is far away from the bus stop sign.

Quote: "Yes, I can, but I think it is not necessary. The bus is always coming soon, I don't need to wait for a long time. For this shelter, I think it is a little far from the bus stop sign, so even if it is necessary, like the bad weather, I would not use the shelter."

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Carol

Age: 19

Work Life: She is passenger and uses the Carpenter Hall bus stop almost every weekday to take the bus between her classes and home. She hardly sit in the shelter but stands inside sometimes. When she is tired, she would like the option to sit.

Key Attributes:
•She thinks the shelter is not large enough.
•She doesn't like to sit
•She thinks the buses are always on time

Quote: "yea, sometimes I feel tired, I can sit and have a rest."
"for this stop, sometimes there are many people waiting, I think this shelter is small, because there are only two seats."

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Vanessa

Age: 22

Work life: She is a passenger, and she uses the Carpenter Hall bus stop on each Tuesday and Thursday to take the bus. She sometimes likes to sit inside the shelter while waiting for the bus.

Key Attribute:
•She thinks the shelter is good enough for her use
•She thinks the shelter is useful, especially in the bad weather.
•She thinks the buses are always on time.

Quote: “yes, I can sit. And It is useful when rain, snow or other bad weather”
“I don’t know other buses, but no delays for me”

Rachel

Age: 45

Social Life: She lives with her girlfriend in the south of Ithaca, having no children. She really enjoys going to parties during the night and has a whole lot of friends who are still students.

Work Life: She has a double degree in theology and music composition, and works at the music department. She is responsible for organizing all the events of the department, including budgeting and finance, and operations. She is especially responsible for networking with a group of local artists and churches preparing traditional Christian music events open to the public.

Key Attributes:
•She likes drinking and listening to heavy metal music
•She is a devoted Christian
•She loves to read books in all disciplines
•She is willing to go out to the bars with her girlfriend during the night

Quote: “I never feel life is hard but achieving a work-life balance is kind of hard because I have so many interests”

Lydia

Age: 21

Social Life: Her social life is kind of limited since she is from Utah and has very few close friends here. Also, none of the roommates sharing the apartment where she lives are students. She enjoys studying at Cornell and loves the libraries here.

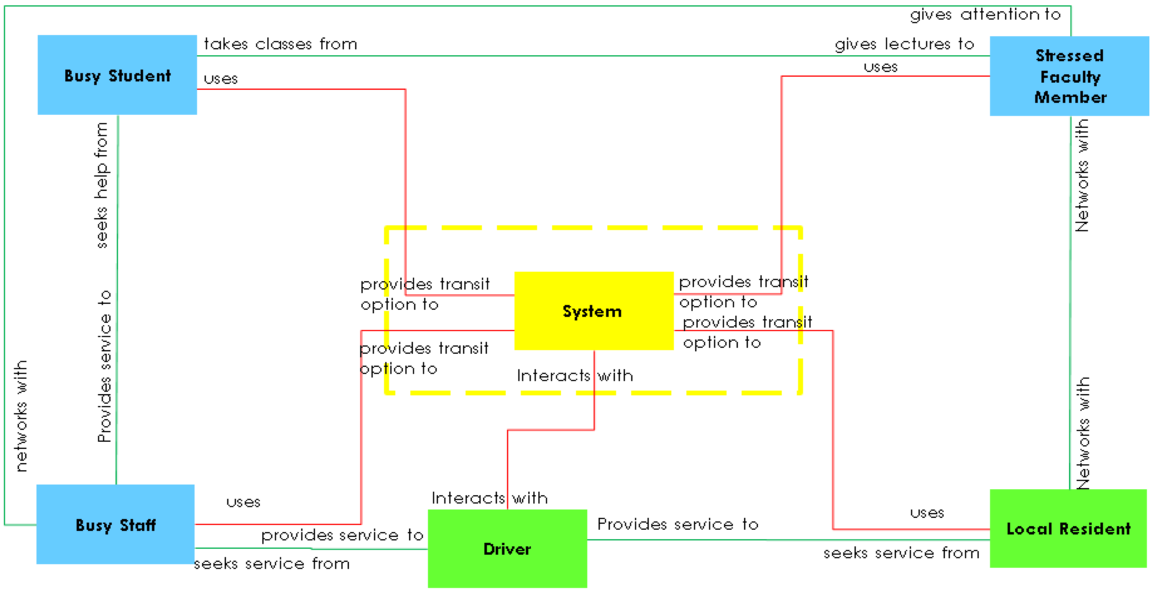
Work Life: She wants to be a software engineer after graduation, so she worked hard doing coding most of the time. Also, she works at the dining hall to pay for her living expenses. She seldom goes out for social networking events.

Key Attributes:
•Hardworking
•Quiet
•She wants to get a job as soon as possible to pay for her student loan

	Quote: “I like to study and work. I do not want to bring much burden to my family.”
	**Hilary** **Age**: 31 **Social Life**: She is currently working at Cornell as a faculty member and her boyfriend is in the Middle East. They are having a hard time trying to stay connected with each other because of the time difference. She attends a lot of meetings and works closely with a group of scientists. **Work life:** She is devoted to her experiments, trying to find another postdoc position, and feeling a lot of pressure. In order to get updated with the latest news in her area, she usually flies out of the country for workshops and seminars. **Key Attribute:** •She hates doing exercise •She is in a fragile relationship with her boyfriend •She has a lot of pressure as a postdoc **Quote:** “I have to work extremely hard since people nowadays are very competitive. Life is hard and I don't even know whether I enjoy the academia path.”

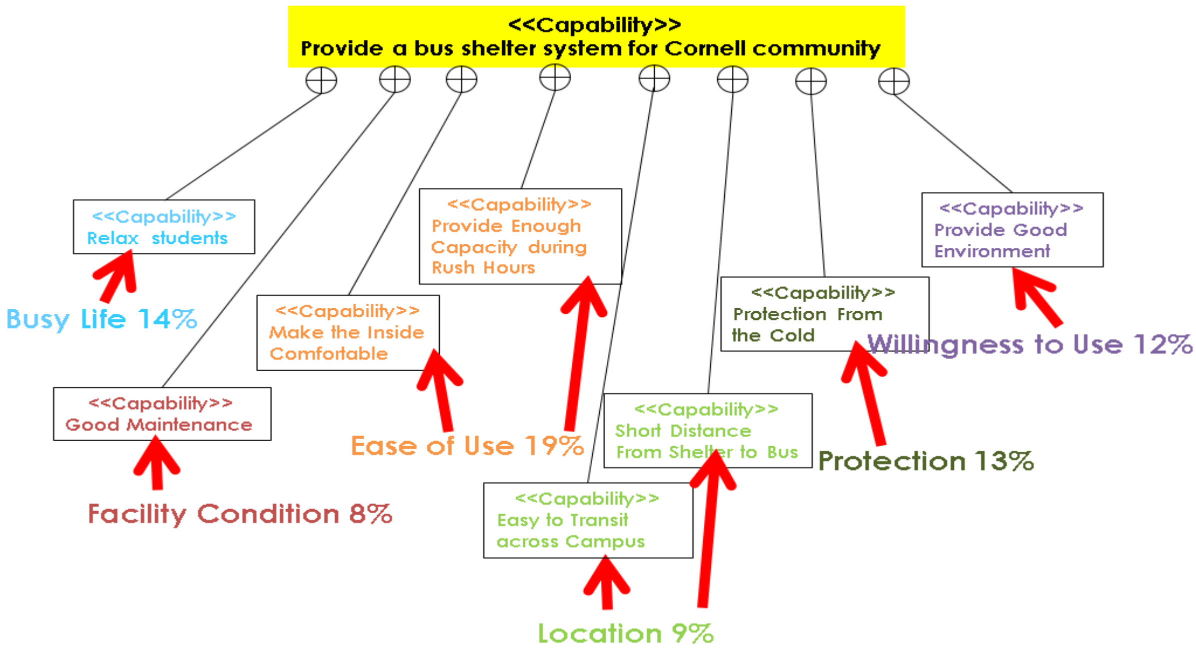
Personas Context Diagram

The following diagram explains how our personas interact with each other and with the system. Based on these interactions we are better able to understand how all of the system’s users are connected and how their needs can be met.



"How Might We" Capabilities Diagram

Based on the aggregated emotional data, we picked the main capabilities of the system as the goals and developed the capabilities diagram. It would help people better understand how the system would function and how much effort they should pay to certain parts, in preparation for future design work, both for the shelters themselves, as well as for the placement of the shelters



Meeting with Stakeholders

In early November, the team met with TCAT to discuss stakeholder objectives for our work in the coming semesters and the data extracts that we would need from TCAT to prepare the bus shelter database. The key ideas from the discussion were as follows:

TCAT's Objectives for Master Plan Team

They would like for the Master Plan team to continue to provide benchmarks for TCAT bus shelters based on *human-centered metrics*, such as rider comfort and local stop conditions, rather than based purely on ridership numbers and bus schedules (which is the current means of determining bus shelter locations).

TCAT Data

TCAT is willing to provide our team with the data we need to carry out analyses of bus shelters and to create a bus shelter database (through exported CSV files, and through Tableau Public). In the future, TCAT is looking to work with Cornell University itself to allow for a copy of TCAT's full database to be stored on Cornell campus, and allowing teams such as CUSD to directly use said database. In the interim, our team will focus on representative samples of the data, for both privacy reasons and because of the logistics of transferring large data files.

Our Future Work

Much of the work completed in the Fall 2019 was gathering and organizing relevant information, which allowed the Master Plan team to better understand stakeholder needs and relationships, while laying down a strong foundation for future semesters' work. As stated in the previous section, TCAT would like for user experience metrics, similar to those that we investigated this semester, to be major factors driving the design and layout of the bus shelter network in the future.

With the knowledge gained from the customer and the field, one focus of the Spring 2020 semester will be converting customer experiences into quantifiable metrics. This will require further unpacking of the empathy fieldwork to rider needs at the start of next semester. Once the primary needs of the rider have been determined, the Master Plan team will determine empirical means of measuring these factors. For instance, factors such as space, comfort, safety, communication, etc. are all important to riders; however, the best ways for us to measure these metrics has yet to be determined though.

In parallel with the effort to measure and meet rider requirements, the Master Plan Team will continue the effort to develop a system for decision-makers. This system will be used to determine shelter construction projects. The system will need to house, display, and potentially interpret user experience data alongside more traditional metrics like ridership. With these together in one flexible and easily accessible system, shelter location and bus routes can be optimized. With this information, decision-makers will be able to more efficiently determine shelter construction needs which will drive more rapid incorporation of CUSD's Sustainable Mobility Shelters.

The Master Plan team laid great groundwork this semester and relishes the opportunity to keep building a wholly new way to look at bus stops and shelters in the TCAT network.

Appendix

Empathy Fieldwork Unpacking

1st p – Leo (passenger) @ Uris Hall across street - October 2019 WEEKDAY 9am

1st p = immersion

- Needed to use the shelter
- Wanted to sit on the bench
- Had to wait for the bus
- Had to run to catch the bus when bus is coming
- Had to catch the classes

I need to try to use the shelter

I feel comfortable because there is nobody in the shelter

I need to catch the bus otherwise I will be late for next class

Why is nobody using the shelter?

It is cold outside but warmer in the shelter

The shelter is not new, but not old

Is there somewhere I can charge my phone?

It will be more useful if the shelter is more functional

I feel happy when the bus is coming

N Catch the classes | Use the shelter | Have a rest in the shelter | Take the bus

I Few people use the shelter | Shelter can keep warmer than outside

S The shelter is a little far away from the stop sigh(where buses stop)

Tensions
Contradictions
Consistencies
Synergies
Hmm...?

2nd p – Carol (student) @ Uris Hall across street- October 2019 WEEKDY 9am

2nd p = engagement

I went to this stop to interview a passenger about how they use the shelter. I saw there is a girl waiting for the bus.
"Hi, I am doing a project about how passengers use the shelter, can I ask you some questions?" "Sure"

"Can I know your name?" "Carol"

"How often are you in this stop?" "Almost every weekday"

"How often do you use the shelter?" "Hardly, unless it is very cold, or heavy rain, or heavy wind, in bad weather."

"Why don't you wait in the shelter? You can sit on the bench and have a rest." "Yes, I can, but I think it is not necessary. The bus is always coming soon, I don't need to wait for long time. For this shelter, I think it is a little far from the bus stop sign, so even if it is necessary, like the bad weather, I would not use the shelter."

"How do you think the shelter?" "Yes, it is designed well, it should be useful in the winter."

"Thank you very much" "No problem"
I ended the interview because the bus was coming.

Carol think it may be interesting and the bus is not coming, so she can enjoy the interview while waiting.

Carol believes she is an appropriate passenger to be taken this interview because she usually waits for bus in this stop.

Carol does not satisfy the design of the shelter and bus sign, she thinks they are far away.

Carol thinks the shelter should be useful for some special moments.

N Wait for bus | use the shelter | Go to classes or go home | have fun when waiting

I Shelter is useful in bad weather

S People do not need to sit for most time

Tensions
Contradictions
Consistencies
Synergies
Hmm...?

3rd p – Leo (passenger) @ Uris Hall across street – October 2019 WEEKDY 9am

3rd p = observation

WHAT/HOW	WHY
Only one passenger is waiting for the bus.	bc it is the start of the day, students need to go to classes.
The passenger is stand outside the shelter and next to the bus sign.	bc the shelter is far from the bus sign, the passenger do not wait in the shelter.
The passenger is playing his phone while waiting for the bus.	bc it is a sunny day, no wind, no rain and no snow, it is not cold, the passenger do not wait in the shelter.
The passenger is not anxious.	- bc the time is enough to catch the next class.
The bus comes in 5 mins.	- bc the passenger usually wait for bus at this stop.

N Have fun during waiting | Wait for the bus | Catch the classes or go home

I Passenger don't sit in the shelter | Buses are usually on time

S

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

1st p – Leo (passenger) @ Carpenter Hall- October 2019 WEEKDAY 9am

1st p = immersion

- Needed to use the shelter
- Wanted to sit on the bench
- Had to wait for the bus
- Had to catch the classes

I need to try to use the shelter

The shelter is small, I feel uncomfortable when I sit inside

Why the shelter is wide open?

How can it keep warm inside during winter?

I need to catch the bus otherwise I will be late for next class

The seats are not clean.

Why is nobody using the shelter?

It is cold outside and also cold in the shelter

The shelter is not new, but not old

It will be more useful if the shelter is more functional

I feel happy when the bus is coming

N Catch the classes | Use the shelter | Have a rest in the shelter | Take the bus

I No use the shelter | The shelter cannot keep warm | The seats are not clean

S

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

2nd p – Carol and Vanessa (students) @ Carpenter Hall - October 2019 WEEKDY 9am

2nd p = engagement

I went to this stop to interview a passenger about how they use the shelter. I interviewed two females. They are students.

"Hi, I am doing a project about how passengers use the shelter, can I ask you some questions?" **C and V**: "Sure"

"How often are you in this stop?" **C**: "Almost every weekday" **V**: "Only Tu and Th I have class here, so about twice a week."

"How often do you use the shelter?" **C** "Hardly." **V**: "Sometimes I use it"
"How do you use the shelter?" **C**: "standing inside" **V**: "sit inside"
"Are the buses usually on time?" **C**: "Sometimes, but within 5 mins" **V**: "I don't know other buses, but no delays for me"

"Is the useful for you?" **C**: "yea, sometimes I feel tired, I can sit can have a rest." **V**: "yes, I can sit. And It is useful when raining, snowing or other bad weathers"

"Do you have some suggestions?" **C**: "for this stop, sometimes there are many people waiting, I think this shelter is small, bc there are only two seats." **V**: "I think it is good enough."

They were leaving when bus was coming.

Carol and Vanessa think it may be interesting and it is good to help me.

Carol believes she is an appropriate passenger to be taken this interview because she usually waits for bus in this stop.

Carol and Vanessa think the shelter is useful but will be better if it can be developed.

Carol thinks there are some shortcomings for the current shelter.

N — Wait for bus | use the shelter | Go to classes or go home | have fun when waiting

I — Shelter is useful in bad weather | Shelter need to be improved | Buses are usually on time

S — Most People do not need to sit

Tensions
Contradictions
Consistencies
Synergies
Hmm...?

3rd p – Leo (passenger) @ Capenter Hall – October 2019 WEEKDY 9am

3rd p = observation

WHAT/HOW	WHY
4 passengers are waiting for the bus.	bc it is the start of the day, students need to go to classes.
1 passenger is standing inside the shelter.	- bc waiting is boring, they need to find something interesting to do.
3 passengers are standing outside the shelter.	- bc it is a sunny day, no wind, no rain and no snow, it is not cold, the passenger do not wait in the shelter.
2 passengers are playing they phones.	- bc the time is enough to catch the next class.
1 passenger is listening to the music.	- bc the passenger usually wait for bus at this stop.
Bus comes in 6 mins; all passengers take this bus.	- bc the buses are always on time; they don't need to wait for a long time.
The passengers are not anxious.	- bc they think the seats are not clean.

N — Have fun during waiting | Wait for the bus | Catch the classes or go home

I — Nobody sits in the shelter | Buses are usually on time

S

Tensions
Contradictions
Consistencies
Synergies
Hmm...?

1st p – Wubing (passenger) @ Kennedy Hall – Weekday Afternoon

1st p = immersion

Facts

Very large bus shelter
Lots of buses passing by
2-3 people sitting in the bus stop, a few standing inside
Lots of people take Route 82 – go to Hasbrouck
I stand in the shelter –most people are standing
I look at my phone to kill time

Emotions

- Feeling awkward sitting down
- Would like to sit in front of Bus Stop Bagels if it is not that cold
- Why people do not like sitting down? Maybe not enough space
- I wanted to get on the bus as quickly as possible - it was cold outside
- I feel uncomfortable when groups of other people talking loudly next to me

N Have protection from the elements | More space for sitting down | More space for privacy

I Collaborate well with the surrounding utiities, e.g. Bus Stop Bagels

S People do not feel comfortable sitting in the shelter

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

1st p – Wubing (passenger) @ Corson Mudd Hall – Weekday Afternoon

1st p = immersion

Facts

Medium Size bus shelter

Lots of buses passing by but going to places I do not know

All standing outside

I stand outside in case of missing the bus

The bus stop is far from the shelter

Emotions

- Cannot sit down because of the location and feel tired
- Worried - It might be better if I walk to Dairy Bar instead of taking the bus
- It is super hard to wait for buses here and I hate it
- I feel good walking to Dairy Bar

N Have protection from the elements | Closer to where the bus stops

I Good view inside the bus stop | Comfort when sitting inside

S Not a good choice to wait for buses here

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

2nd p – Cathy (faculty) @ Kennedy Hall - Weekday Afternoon Rush Hour

3rd p = observation

Saying/Doing	Believing/Feeling
• It would still be cold during winter • Not enough space during rush hours • I always take the bus back home from Mann library • I live in downtown but there are not many buses from here going that way during the night • Sometimes I prefer walking to Uris Hall to take the bus because of the delay • I seldom take bus during winter because it is extremely cold and buses always delay	• People need more routes going different directions during the night • It's very cold outside - so shelter is important • The shelter could not provide enough space • The shelter could not protect enough protection from the cold and wind

N Have protection from the elements | Protection from cold

I The bus system itself is pretty decent | People wait inside dining hall for buses | User experience is bad

S The shelter would not provide enough space during rush hours

Tensions
Contradictions
Consistencies
Synergies
Hmm...?

2nd p – Cathy (faculty) @ Corson Mudd Hall - Weekday Afternoon Rush Hour

2nd p = engagement

Saying/Doing	Believing/Feeling
• It is the worst bus shelter ever, why they build one that could not be used? • During winter, the shelter could not protect us from wind and snow • The shelter is far away from where the bus stops • I sometimes hide behind the shelter to protect myself from the wind • There should be more light for us to find the shelter • The glass reflects the light and makes it hard to see the outside during the night when in the shelter	• A new shelter with a terrible location • The shelter could not provide enough protect for people • The shelter is hard to find • The sight is not good in the shelter

N Feel safe | Protection from the Elements | Transportation between classes

I Enough light in the shelter

S An almost useless shelter

Tensions
Contradictions
Consistencies
Synergies
Hmm...?

3rd p – Kennedy Hall - Weekday Afternoon

2nd p = engagement

WHAT/HOW

- Most people standing outside
- Most people inside are standing
- Maximum: around 10 people standing outside, 5 people inside
- Very cold outside
- Most people wait to take Route 82
- Most people take route 82 here to go back to Hasbrouck
- A lot of students take the bus at Kennedy Hall and get off at Uris Hall to go to Olin library and Cornell Store
- Bus Stop Bagels and Trillium Dining Hall is right at the bus stop
- A lot of people sitting right outside Bus Stop Bagels when the weather is good

WHY

- The Ag Quad is a popular place at central campus. Some offices including ISSO and ELSO are located nearby
- It is a bit far away from engineering and humanity buildings
- There is almost no bus from Ag Quad to Johnson School and Rhodes Hall
- Students want to minimize the distance of walking by taking one stop
- The dining hall is also a popular place
- People don't want to sit on cold surfaces
- Sitting on cold surfaces is uncomfortable
- People would like to avoid discomfort during transportation

N Enough shelter space | Transportation between classes | Serve a lot of people

I Shelters looks new and nice | Have fun when waiting for bus

S Not as much people taking buses as expected

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

3rd p – Corson Mudd Hall- Weekday Afternoon

3rd p = observation

WHAT/HOW

- A few people around but most of them do not stay in the shelter
- Most people inside are standing
- Maximum: around 10 people standing outside, 0 people inside
- Very cold outside
- Buses from this stop go to further areas including other counties and staff buildings
- Most people get off here heading to Mann Library.

WHY

- Lots of buildings in this area
- People don't want to sit on cold surfaces
- Sitting on cold surfaces is uncomfortable
- People would like to avoid discomfort during transportation
- The shelter is far from where the bus stops

N Serve a lot of people | Have protection | Convenience getting on the bus

I Shelter location is inappropriate | Shelter is useful in bad weather

S

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

3rd p – Ziyu (passenger) @ Dairy Bar across Street – October 2019 WEEKDY 10am

3rd p = observation

WHAT/HOW

- Most people standing outside
- Most people inside are standing
- Most people outside are exposed to wind
- Over 80% people get on Route 82 bus
- Maximum: around 15 people standing outside, 6 people inside
- Very windy outside during empathy fieldwork

WHY

- The shelter is small
- Dusty bench
- The only bus stop for people from Dairy Bar and other buildings to go west
- Poor maintenance/condition

N Many students school nearby | Get from Dairy Bar to central campus

I Poor maintenance/condition

S Poor condition of shelter

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Ziyu (passenger) @ Bradfield – October 2019 WEEKDY 9am

2nd p = engagement

WHAT/HOW

- Most people standing inside
- Maximum: around 4 people standing outside, 8 people inside
- The shelter is far from the entrance of Bradfield

Interview results:
Maria often waits inside this stop. She likes sitting on the bench in fall. However, she always waits inside Bradfield hall in winter and runs towards the bus stop when the bus comes.

WHY

- The shelter is roomy
- The only bus stop nearby to go west
- Good maintenance/condition

N Many students school nearby

I Good condition

S Poor condition of shelter

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Ziyu (passenger) @ Bradfield Hall Across Street – October 2019 WEEKDY 3pm — 2nd p = engagement

WHAT/HOW

- Most people standing outside
- Over 80% people get on Route 82 bus
- Maximum: around 8 people standing outside, 2 people inside
- Very windy outside during empathy fieldwork

Interview results:
Macy dislikes the long distance between the shelter and bus stop. She needs to run towards the bus when the bus comes, if she stays inside the shelter. Thus,she always stand near the bus stop point.

WHY

- The shelter is 12 meters away from where buses actually stop
- Not
- Good maintenance/condition

N Not many student houses nearby | Only one side of street has regular bus service

I Shelters not inviting

S The shelter is far from where buses actually stop

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Xiaoyu (passenger) @ Lincoin Hall – October 2019 WEEKDY 1:45 pm — 3rd p = observation

WHAT/HOW

- Very small shelter, can only take 2-3 people
- People are waiting outside
- Needs a larger seat.

Results:
The shelter is too small, while there should be enough room for a larger one. Most of the people are standing outside since the seat is only good for one person, and the standing area can take another one. Actually I think there is no need to replace the current shelter as it is not a busy one.

WHY

- The shetler is very close to the next stop (2 min walk)
- It is NOT a busy stop

N More seats for people

I Too many close stops nearby

S Not many people are waiting here

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Xiaoyu (passenger) @ Rockfeller Hall – October 2019 WEEKDY 2pm

3rd p = observation

WHAT/HOW	WHY
• Most of the people are standing outside • Many are sitting outside • No one is sitting inside • Relatively crowded stop. **Results:** **This is a pretty busy bus stop where I think a maximum of 20 people are waiting for buses home. I think the shelter is definitely too small for 10 people to sit, but could probably take them in if standing. When the weather gets colder, people will all try to get in. More observations are needed in the winter.**	• Busy stop • There is no enough room to sit inside • There is a long concrete stage that people can sit on • It is not so cold outside

N More seats/area for people in the winter

I Busy stop

S A lot of people choose to sit outsied on the concrete

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Xiaoyu (passenger) @ Vet School – October 2019 WEEKDY pm

2nd p = engagement

WHAT/HOW	WHY
• People are waiting outside • Not many people here, up to 6 • Not many bus routes stop here **Interview results:** I interviewed a student called Luke for only a few minutes. In conclusion, he doesn't like staying inside as the weather is not too bad. Luke said that it would be great the the new shelter have some bus info indication systems, like what he has seen in the stop of Statler. Besides that, the heater will be a plus but not necessary. He said he uses the phone app for bus info so he usually don't stay out for a long time.	• The only bus stop within a relatively large area • A little far away from main campus • Weather is not too cold

N Maybe a heater and indicator

I Far from main campus

S People are not standing in the shelter even when it is not crowded

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Appel Commons - Weekday Morning Rush Hour

3rd p = observation   2nd p = engagement

WHAT/HOW

Dozens of students here waiting for 82 or 83, whichever arrives first. It is drizzling outside, yet only one person stands in the shelter. The biggest problem is that the shelter is not where the bus pulls up to in the bus bay, it is at the other side. A few people sit on the stairs and a few sit on the grass hill. Several students also wait in the lobby of Appel until they see the bus come, then they dart down the path to catch the bus, leading me to believe that a Real-Time indicator inside of Appel would be very beneficial. More than 20 people board the bus every 11 minutes.

Interview results:
Simon always waits outside, never uses the shelter. He stands as well, especially with water and/or snow on the ground. He says he is more likely to use the shelter when it is precipitating, but it is usually full. He believes in general it is a sufficiently sized shelter though.

WHY

- Location that almost all freshmen eat breakfast
- Two major routes that serve central campus
- Rainy weather

- Again, very crowded and popular stop
- Can't afford to miss bus, so he waits outside in the rain

N Place for many freshmen to wait | Real-Time indicator inside of Appel Commons

I Shelter is in bad location and people wait inside before running to stop

S People would rather sit on ground or stairs than on bench in shelter

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Balch @ Thurston - Weekday Afternoon

3rd p = observation

WHAT/HOW

People tend to wait for a little bit, assuming a bus will come, but if it does not they decide to walk north, presumably to Freshman housing on the far end of North campus (RPCC stop would serve). People sit in the shelter, which, although not unique, is clean and in good shape. The garbage cans are off to the side along with a post box, so the stop makes great practical sense. The paved paths across the Balch Lawn are largely inefficient for people using the stop, so most people cut across the grass. An additional path would solve this problem. No crosswalk at Risley makes this a dangerous stop nonetheless.

WHY

- Not sure who is boarding the bus here, but several people are.
- Much quicker way of getting to the High Rises, Low Rises, Townhouses, or RPCC than walking.
- On Weekdays, 82 links this stop to those ones.

N Path across Balch Lawn | To get from south North Campus to north North Campus

I People are willing to walk if bus does not come in a couple minutes

S How much ridership this stop has

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Balch @ Cradit Farm - Weekday Evening

3rd p = observation

WHAT/HOW

Stop has cool, colorful pac-man art on the shelter plastic walls. People sit on the concrete blocks happily when it is nice outside, one block can seat two people and the other four, but it is obstructed by two trash cans and actually can only seat one. These need to be moved. Simple fix. Bus shelter is fairly large but without seats, people stand inside. The bus bay is right next to the shelter, so the location of it is perfect. Some people run when they see the bus coming down Cradit Farm from Appel. No one really gets off here.

WHY

- Can be debated whether this stop is totally necessary, but it is definitely well-used.
- 82 and 83 both stop here and go to Central Campus
- Shelter overall is very nice and has the ability to sit many people outside, but the garbage and recycling need to be moved.
- Balch and Tatkon Center house and provide a central location for Freshmen.

N To have the garbage can moved | To remain as a stop

I The stop has a very high ridership, even though it is close to Appel

Outside seating is successful and should be used as a model

S That there is a contingent that want to do away with this stop

Tensions
Contradictions
Consistencies
Synergies
Hmm...?

Risley - Weekday Afternoon Rush Hour

3rd p = observation

WHAT/HOW

People like to sit or stand under the awning. The style is similar to the shelters at A-Lot but much more open and less dilapidated. People try to figure out when the bus will arrive because it is impossible to see around the Thurston curve or up Wait Ave. Multiple riders check apps on their phones for real-time arrival info. Risley has no crosswalk, so people cross dangerously in front of cars to get to the bus stop. The lightbulb has a slight buzzing noise. The road dips down severely where the bus stops and the wheels go, constantly splashing people with rainwater because water puddles there.

WHY

- Brick helps to block the wind, but doesn't do a great job because it is narrow
- Feels like it was squeezed in - not even a bus bay
- Location is good and has many boarders but they cannot tell when the bus is coming

N Safety via a crosswalk | To receive a bus bay or better drainage

I Many riders use apps at this stop

S How successful the shelter and bench are

Tensions
Contradictions
Consistencies
Synergies
Hmm...?

A Lot Lower - Morning Rush Hour

1st p = immersion 3rd p = observation

WHAT/HOW

People (faculty/staff) avoid bus shelter altogether. No one goes inside; herd effect. People stick to the railing area or the bus loading area and stand. Shelter is horribly dilapidated, wood paneling decomposing, concrete falling apart, benches inside are covered in dust, dark, floor littered with trash, trash cans inside are uninviting, ceiling and wall paint chipping, smelly. Overall the shelter sucks. Outside walls are newly painted. Some folks wait under the shelter's awning, probably even more the case when raining. Bus route inconsistent. When people miss the bus, they decide to walk instead. Some people do not even give the bus a chance, they just walk regardless. But it isn't too cold this morning.

WHY

- Old and not well maintained
- Two stop system confusing, what people do know is that if they miss it, they should walk
- However, this is not always true as the buses don't always run on time
- Needs to be replaced

N To be consolidated into one stop

A Real-Time indicator so people can wait in cars before boarding

I Bus stoppage times are not consistent

Many commuters just decide to walk

Shelter condition is horrible

S Literally not a single person goes in the shelter

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

A Lot Upper - Morning Rush Hour

3rd p = observation 2nd p = engagement

WHAT/HOW

Shelter in better physical shape than the Lower stop, still dilapidated and decaying. About a 1-2 minute walk between the two, enough where you could miss the bus and then miss the bus after trying to get to the lower stop, i.e. Siri. One person ventures into the shelter and puts bag on bench, but does not sit themselves. Wood covered in dust, as if no one has sat down on edges of the benches in months.

Interview
Latasha says she doesn't know how to use the app or even which to use, so she has a slight issue with when the bus comes because it is not always on schedule. She noted that one morning she had to wait an entire 30 minutes to catch an 81. She says she tries to walk now if it is nice out because the bus is not nice enough. Does not have a serious problem with the shelter or the buses, just the timing of them.

WHY

- Gross and uninviting
- Largely similar to the lower stop, but the shelter is poorly maintained and faculty and staff would rather stand and wait in the cold than inside

- Not reliable enough
- Shelter is still functional

N To be consolidated into one stop

Real-Time Indicator

I Shelter condition may not matter as much as expected, bus timing does if not more

No one goes inside the shelter

S Buses spend varying amounts of time bayed here

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Jessup @ Triphammer - Weekday Afternoon

3rd p = observation

WHAT/HOW

Bus stops are desolate. No one is around, a few people get off the 82 bus but this is not a big population center. Southern side of Jessup has only the 82 on weekdays, north side of Jessup has no buses on weekdays. 70 and 72 serve both sides on weekends. The shelter on the north side of Jessup is connected to the headhouse for a sports field and does not let out directly to the bus stop.

WHY

- Not much student housing in the area
- Only one side of street has regular service on weekdays
- Bus shelter on north side doesn't directly access sidewalk
- No bus shelter on south side
- North shelter smelled very bad, was peeling and dilapidated

N Not many student houses nearby | Only one side of street has regular bus service

I Shelters not inviting

S Poor condition of shelter was shocking

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Jessup @ Pleasant Grove - Weekday Afternoon

3rd p = observation

WHAT/HOW

Bus stops are desolate on weekdays. No one is around, a few people get off the 82 bus but this is not a big population center. Southern side of Jessup has only the 82 on weekdays, north side of Jessup has no buses on weekdays. 70 and 72 serve both sides on weekends. Compared to a decent number of people on weekends going to the mall from this stop.

WHY

- Not much student housing in the area
- Too close to Hasbrouck to be efficient but too far to be useful
- No shelter on north side
- No regular bus service on north side

N Not many student houses nearby | Only one side of street has regular bus service

I Location relative to Hasbrouck is not useful

S Thought it'd be useful for Low Rise residents

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Stewart @ University - Weekday Morning

1st p = immersion

Facts

Very large bus shelter, but no buses in sight
Only one other person waiting for bus that never came - she left after it didn't show up.
Route 83 shown on bus stop flag, but it doesn't serve the stop anymore - several other routes do.
I tried to get the bus schedule for this stop, but it's confusing - several routes serve this stop, so it's hard for me to figure out when the next bus is going to arrive.

Emotions

- Feeling quite confused about when the next bus is going to come
- Concerned when it seemed like the bus was late
- Annoyed when the bus didn't come - and it didn't seem like another bus was going to come for a long time
- I thought it was curious that there's such a big bus shelter for such a sparsely-used bus stop
- I wanted to get moving as quickly as possible - it was cold outside

N Have protection from the elements | Know when the bus is coming | Know what routes serve the stop

I The bus flags featuring routes are useful...until they are inaccurate

I There isn't a good way of keeping track of multiple routes' schedules

S That such a nice bus shelter is so poorly utilized

Tensions
Contradictions
Consistencies
Synergies
Hmm...?

Goldwin Smith Hall - Weekday Afternoon Rush Hour

2nd p = engagement

Saying/Doing

- There may have been a front panel on this bus shelter before, which made things much more comfortable
- The one across the street has a light in it - and that makes the other bus shelter feel much safer
- Not much to say - pretty satisfied with bus shelter in general
- Solar panels on them would be a great idea (for powering lights, etc)
- Taking Route 10 to the commons because it's faster than Route 30 (seems like she knows this from experience)
- Route 10 comes every 10 minutes, and she's waiting for it without really checking the schedule

Believing/Feeling

- Public transit is mostly fine - including bus shelters
- This shelter's not fully doing its job because it's missing a front panel that would protect her from the wind and cold
- She doesn't feel a need to check the schedule for Route 10 - because it comes so frequently
- Safety is number one issue on her mind with transit
    - Lights make bus shelters feel safer
- Would be good to have more than a bare-bones shelter, with amenities that could be powered by solar panels

N Safety | Protection from the Elements

I Lights greatly improve experience

I Certain routes come frequently enough for people to not need schedules

S Ordinary users see the need for solar panels

Tensions
Contradictions
Consistencies
Synergies
Hmm...?

Goldwin Smith Hall - Weekday Afternoon Rush Hour

2nd p = engagement

Saying/Doing

- The shelter could be more protective against the elements
- The shelter gets very packed - not all people fit during rush hour
- Not a great experience during snowy/cold days and rainy days
- She'll wait inside of Klarman Hall and run out when the bus arrives sometimes to escape the elements
- The downtown bus shelter is better because it's fully enclosed, but it's still not great
- The bus is pretty frequent here
- In Europe there are actual buildings to wait in
- Bus shelters are pretty good, for a university campus

Believing/Feeling

- The public transportation here is a step down from what people find in Europe
- It's very cold outside - so shelter is at the top of her mind
  - Not just protection from the wind (though that's important), but protection from the cold as well
- The bus service itself is fine, but the experience before boarding the bus leaves much to be desired
- But she can't expect too much from a university campus, much less one in the United States

N Have protection from the elements | Protection from cold

I The bus system itself is pretty decent | People wait inside of buildings for bus

User experience could be improved

S That people will wait all the way inside of Klarman

- Tensions
- Contradictions
- Consistencies
- Synergies
- Hmm...?

Rockefeller Hall - Weekday Afternoon Rush Hour

3rd p = observation

What/How

- Most people standing outside
- Most people inside are standing
- Nobody sitting on the snow-covered ledge outside, unlike during the summer
- ½ of people get on Route 82 bus, most of the rest get on route 30, last straggler gets on route 81 bus, then shelter empty
- Shelter quickly fills up again
- Maximum: around 15 people standing outside, 5 people inside
- Very cold outside during empathy fieldwork
- There is a light inside, so the shelter's decently well lit

Why

- Because people don't want to sit on cold surfaces
- Because sitting on cold surfaces is uncomfortable
- Because people would like to avoid discomfort during transportation
- Because there's no room in the shelter
- Because there are too many people wanting to take the bus
- Because people want to get home with the least effort and discomfort
- Because there's a tradeoff between the discomfort of the cold and the discomfort of being crammed into a bus shelter with too many others

N Protection from the Elements | Comfort

I People don't sit in the cold - outside and inside the bus shelter

People would rather wait outside than have their personal space violated

S The bus shelter itself wasn't excessively packed

- Tensions
- Contradictions
- Consistencies
- Synergies
- Hmm...?