SYSEN 5900-CUSD Sustainable Mobility-Shelter

CORNELL UNIVERSITY
SUSTAINABLE DESIGN

Cornell University
Systems Engineering

Disclaimer of Warranties

The following report might be sent to external entities and organizations. Because this project is run by students and not a professional firm, the team has to officially inform the external entities and organizations of the following statement:

CUSD (and the CUSD Sustainable Mobility team - Shelter) is not a professional engineering firm. Therefore all the deliverables that we produce have to be intended as recommendations or guidelines, which can be used by external entities and organizations at their discretion. Furthermore, before any of the materials provided by CUSD can be implemented, they must achieve the needed verifications and authorizations (such as PE stamp) of external licensed professionals, which cannot be provided by CUSD.

With all above said we are also stating that:

While reasonable efforts have been made to assure that the information in the deliverable is accurate, the information is provided for convenience and reference only and without warranty of any kind. Any reliance that recipient places on such information is therefore strictly at its' own risk.

The University is not responsible for recipient's reliance on the information in this deliverable or errors related to the information contained in the deliverable. All such errors are subject to correction. No warranty, expressed or implied, is made regarding accuracy, adequacy, completeness, legality, reliability or usefulness of any information. This disclaimer applies to both isolated and aggregate uses of the information.

The University provides this information on an "as is" basis. All warranties of any kind, express or implied, including but not limited to the implied warranties of merchantability, fitness for a particular purpose, freedom from contamination by computer viruses and non-infringement of proprietary rights are disclaimed. If you have obtained information, originally created by the University, from a source other than the University, be aware that electronic data can be altered subsequent to original distribution. Data can also quickly become out-of-date. It is recommended that careful attention be paid to the contents of any data associated with a file.

Recipient HEREBY agrees to HOLD, Cornell University, its' respective trustees, officers, agents, volunteers, and employees (collectively, "Released Parties") HARMLESS from any liabilities, damages, expenses, causes of action, claims, or demands of any nature whatsoever, including any claims of negligence related to the recipient's reliance on the information, research data or findings in this deliverable.

Best Regards,
CUSD – Sustainable Education Mobility Team - Shelter

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 both Sirietta Simoncini and Wenqi Yi.

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 Masterplan.

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 Masterplan team, have been in contact with Cornell Transportation and Cornell Landscape Architecture to discuss the potential of implementing the first shelter on campus.

The Masterplan 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 Masterplan team was formed to address this issue.

In addition to cataloging the current TCAT stops and shelters, the Masterplan 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 the Masterplan is 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 Masterplan 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 Masterplan team have come to the consensus that it would be best to consolidate the two existing shelters and replace them with one large shelter.

SHELTER DESIGN TEAM

Leo Andriuk	Nick Casazzone	August Cudeck
Kamille Gomez	Isabella Hubsch	Joaquin Jerez
Peter Kaplinsky	Paul Osuma	Jack Pertschuk
Krithik Ranjan	Wei-ling Sun	Cole Thienes
Amit Ajit Verghese	David Van Wijk	

MASTERPLAN TEAM

Rujuta Desai	Vincent Dipietra	Alex Goddard
Xiji Hong	Peter McKendall	Everett Sanderson
Marielle Sheck	Yutong Xu	Robert Zhang

ADVISORS

Sirietta Simoncini

Wenqi Yi

Spring 2019

Shelter

Introduction

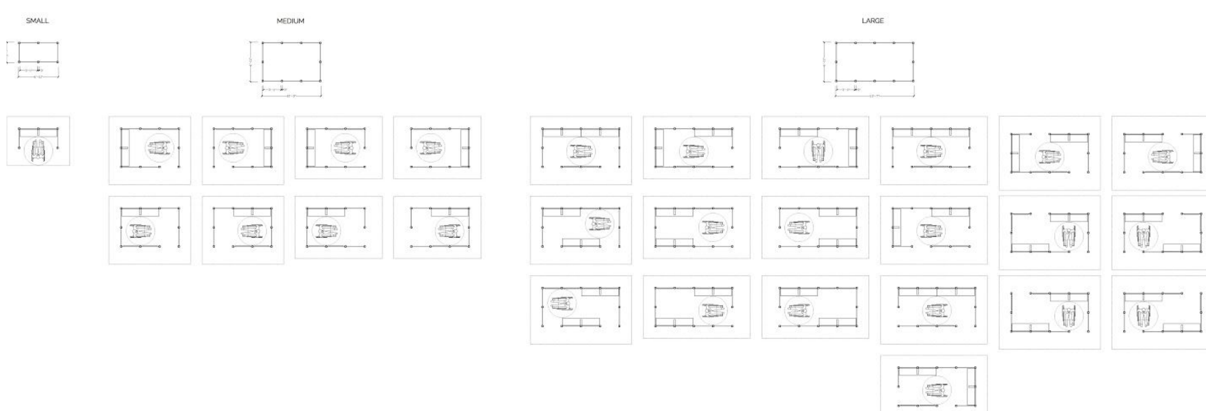
This semester we worked on fleshing out the details of the shelter. We've been working on the shelter for 3 years now and we've reached a point where we have a finalized design and are in the prototyping phase. Due to the size of the shelter, we wanted to avoid any issues that we could run into before 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.

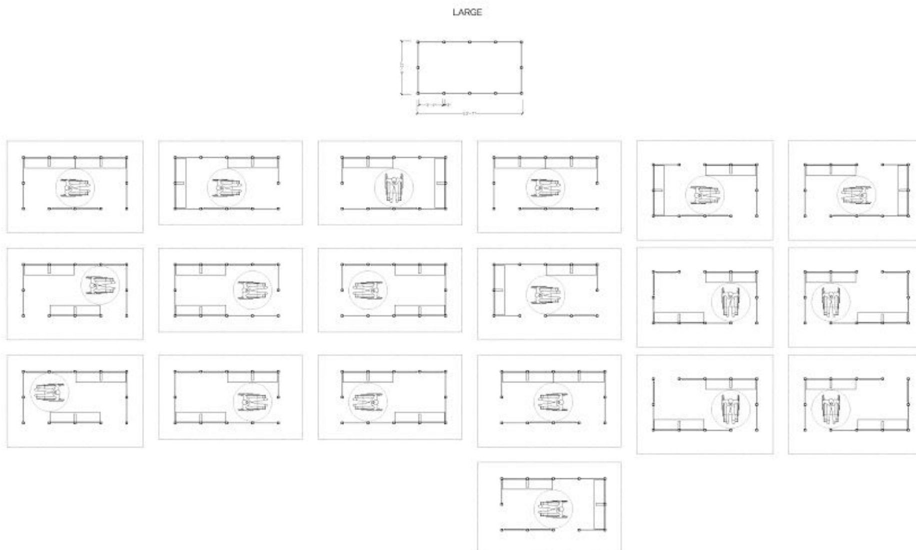
Our Shelter

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.

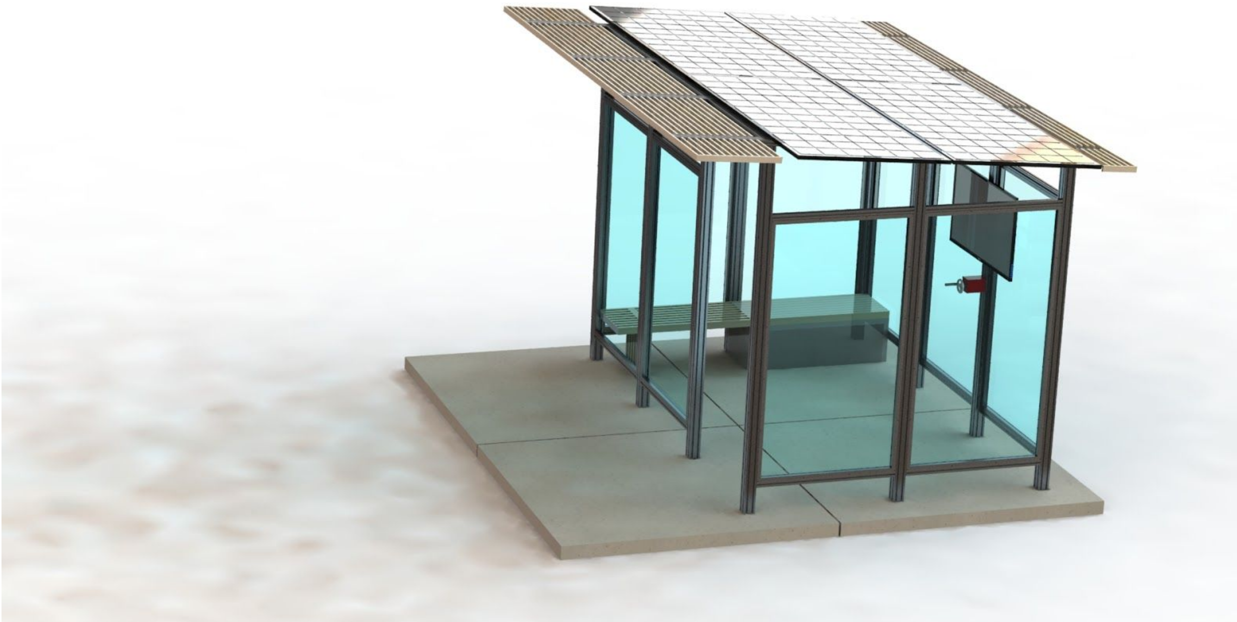


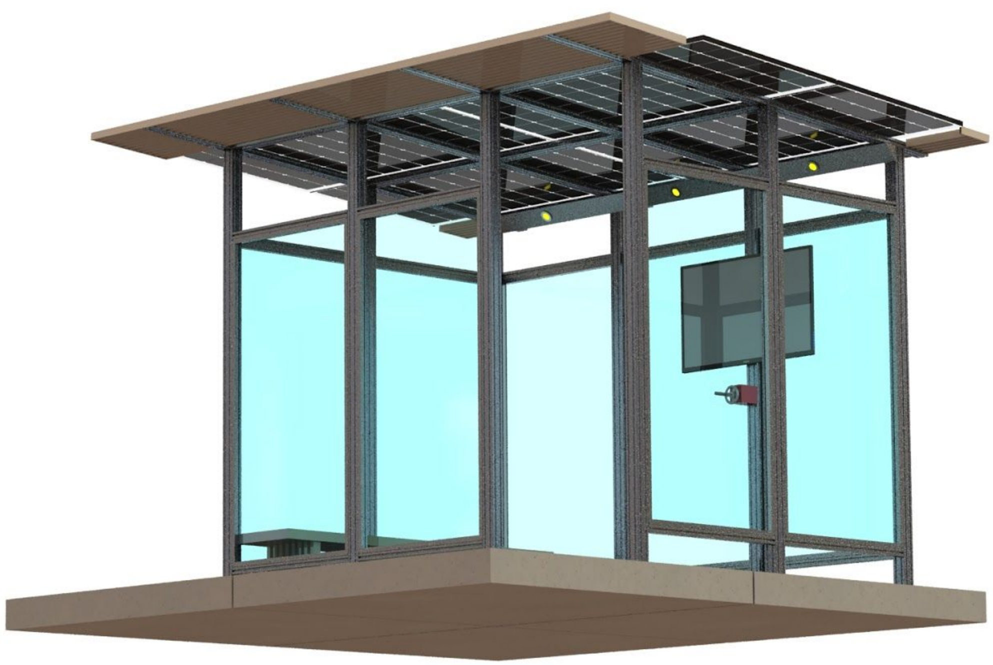
Layout and feature variations of the large shelter.

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





Manufacturing Plans

Bench Plans

The bench is built out of concrete and wood to create an elegant storage unit for the electronics. The concrete is poured into a reusable mold on site. The wooden beams run along the bench providing a warmer surface for people to sit on. This is important for a bench in Ithaca where temperature fluctuates. The beams are attached to the mold, making the concrete almost flush with the wood. When the mold is removed, the beams are cemented into place. The other side of the bench is supported by what seems to be an extension of the bench. These wooden pieces are connected using mortise and tenons. The ends of the beams are secured together using a metal plate. The metal plate is then bolted to the ground. The electrical compartments will by concealed by sheet metal that will be bolted to the concrete.

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

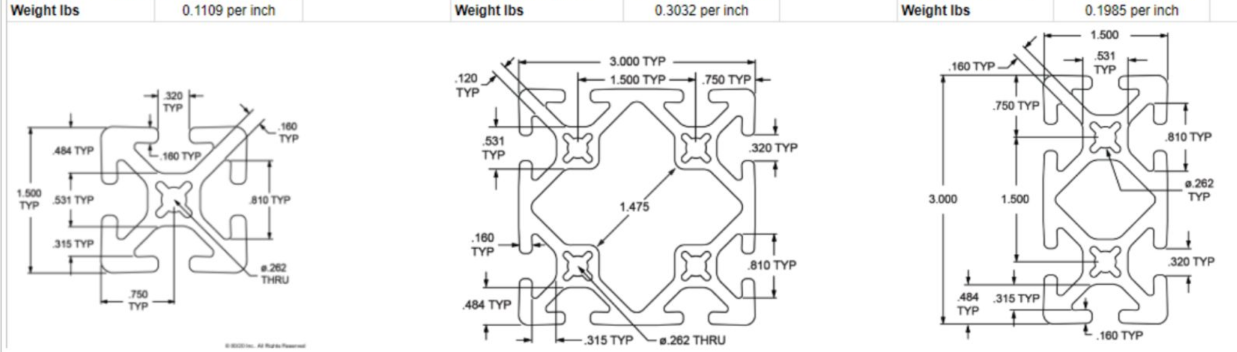


Figure 1: T-slot profiles

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.

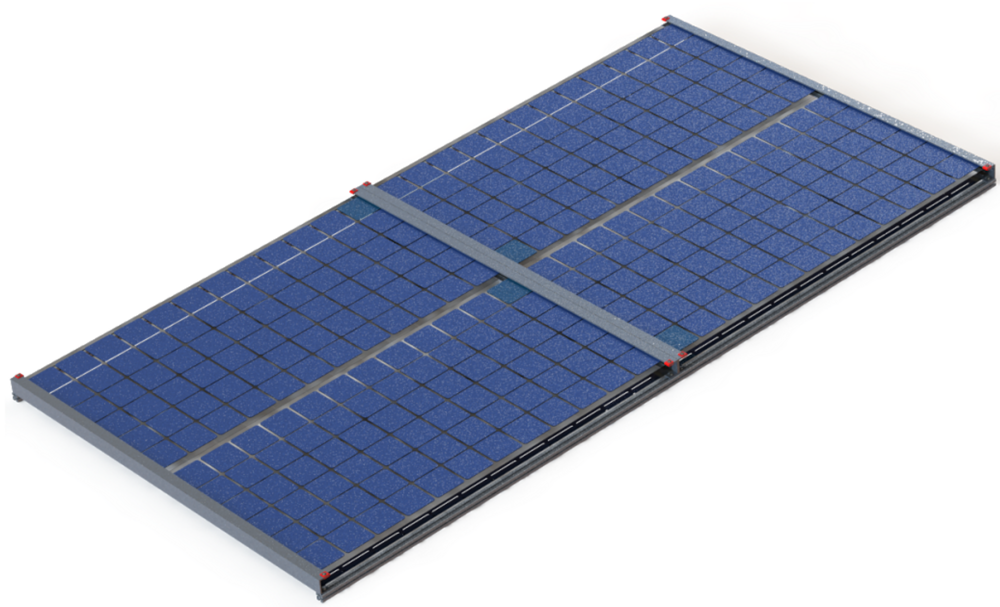


Figure 2: Solar Panel Roof Racking Assembly

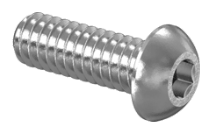
Recent design changes to the roof racking system this semester took place to ensure that the panels would still qualify for coverage under Lumos' warranty. Weather-resistant EPDM square gaskets with a 60A durometer were implemented to protect the glass panel from scratching and cracking at the interface 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 0.25'' holes and tapping them on the bars 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.

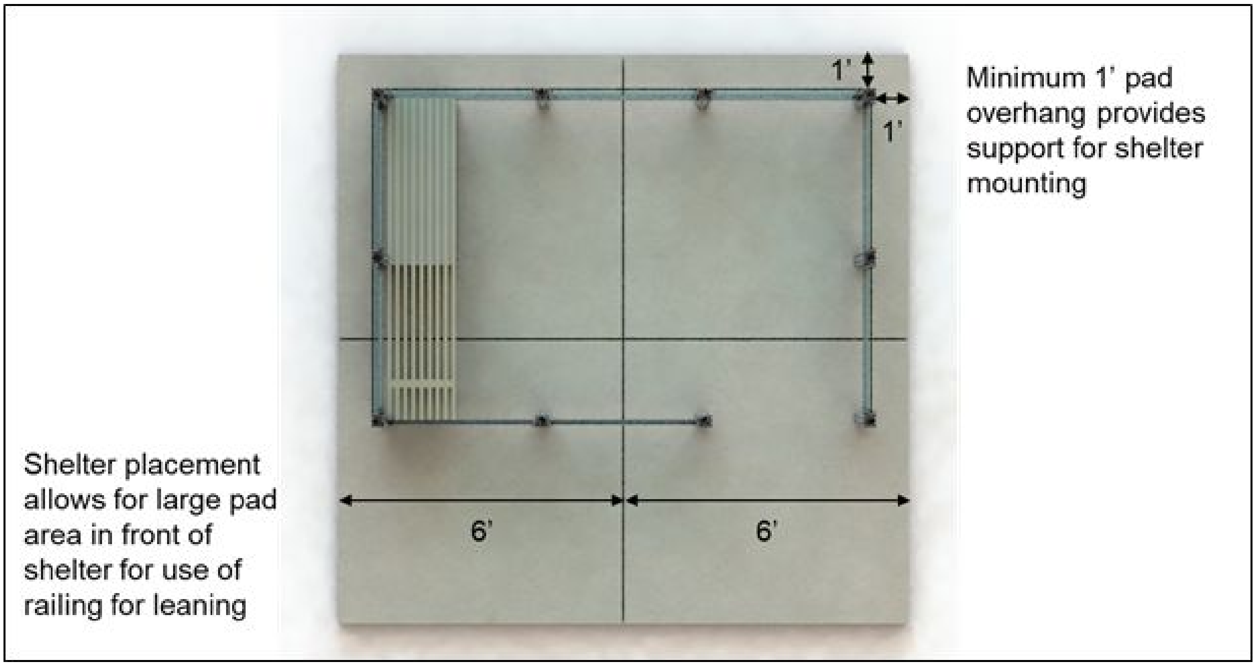


Figure 3: Concrete Pad Expansion and Shelter Placement

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.

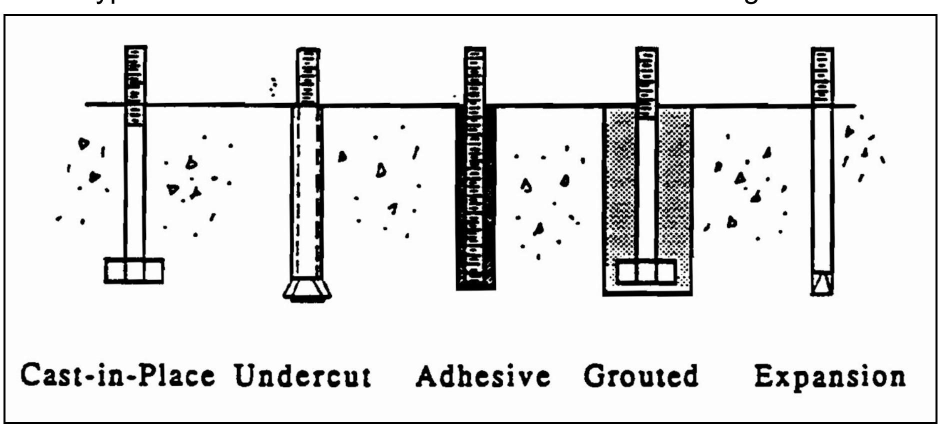
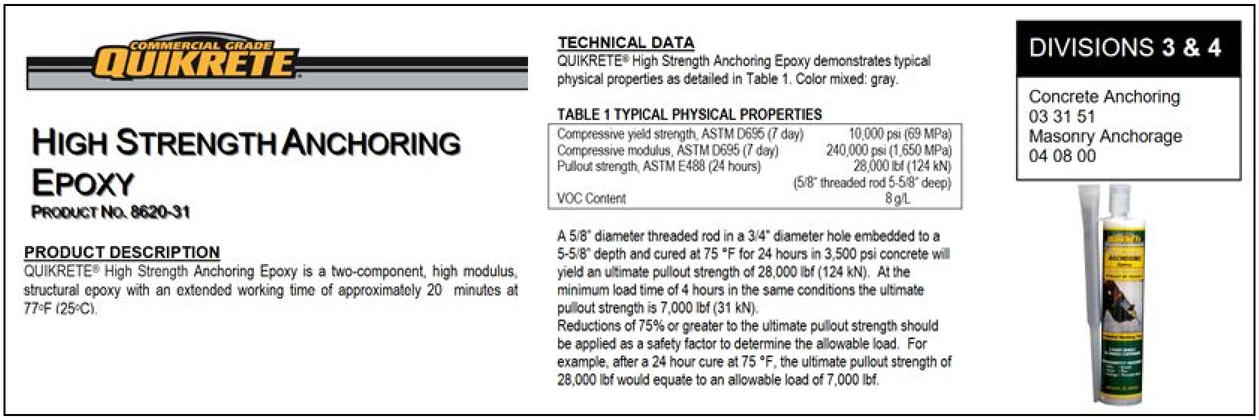


Figure 4: Anchor Bolt/Mechanism Types

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 5: 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.

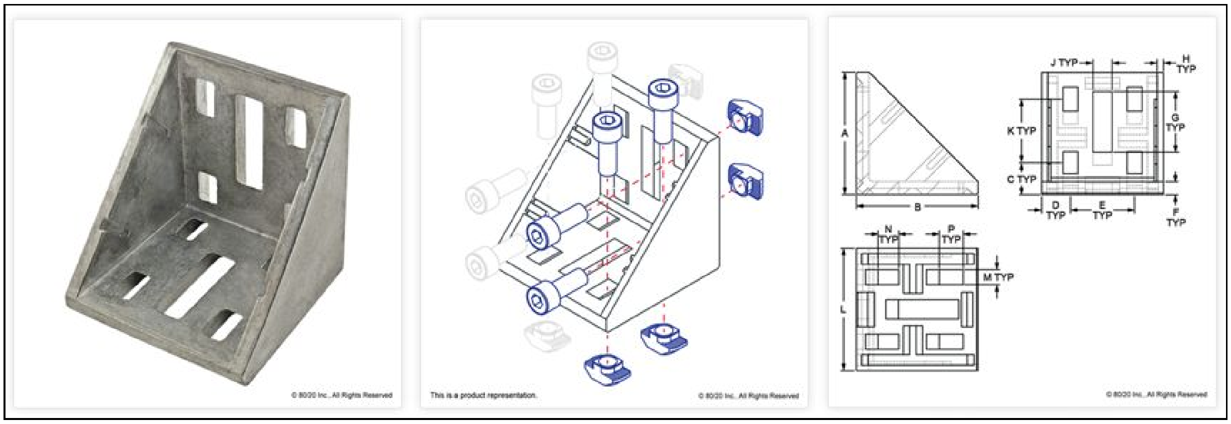


Figure 6: 80/20 Floor Mount Bracket P/N 14095

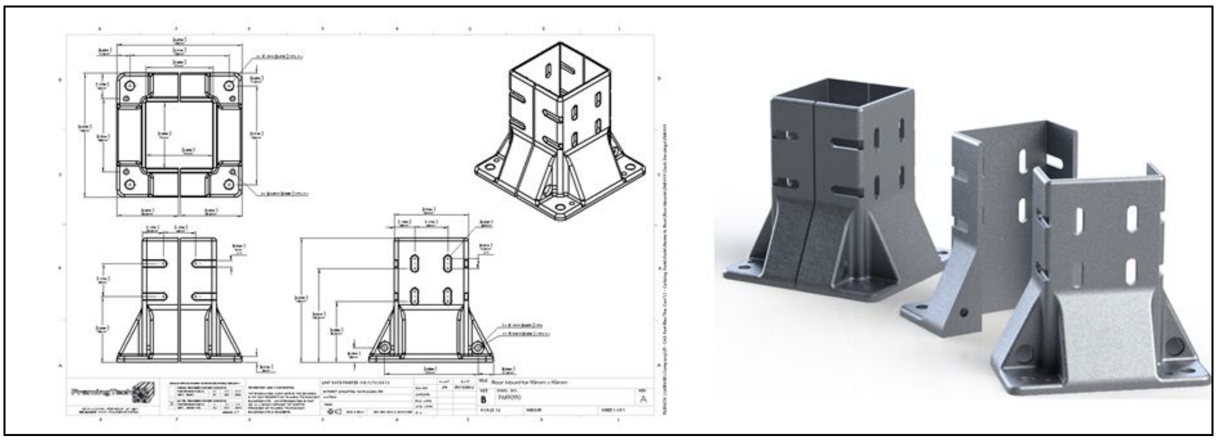


Figure 7: Framing Tech Floor Mount Base P/N FM9090

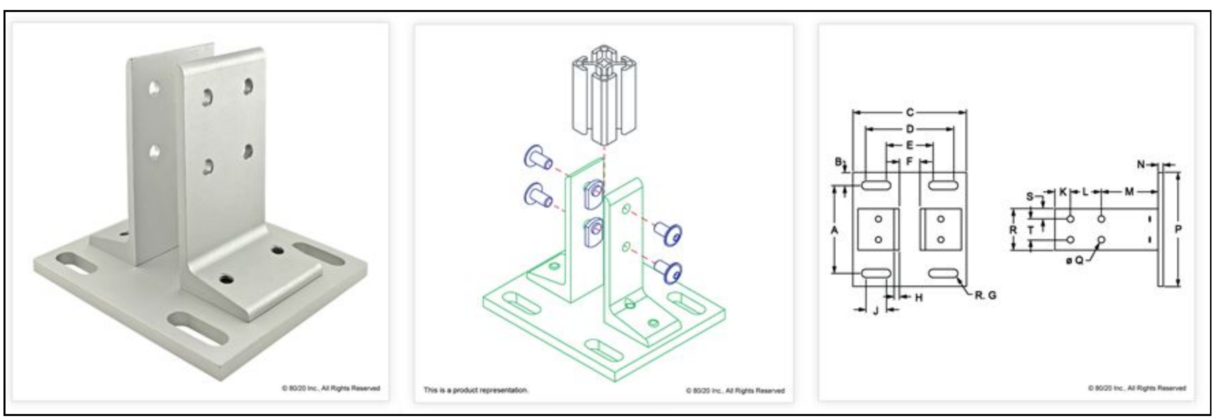


Figure 8: 80/20 15 Series Floor Mount Base P/N 2400

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 9: 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 10: 80/20 Part Number 3320: 5/16-18 Flanged Button Head Socket Cap Screw and T-Nut

Figure 11: Stainless Steel Tamper-Resistant Screws and Driver

Figure 12: Stainless Steel Tamper-Resistant Grooved Nuts and Driver

LED C-Channel Plans

The functionality of the indicator lights has not changed since last semester:

“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 change its color from white (indicating no bus arriving soon) to blue (indicating a bus is arriving within two minutes). 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 walk/run up to the stop when the indicator lights starts to change colors, preventing missed bus trips.

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 cannot see the bus-time information displayed on the LCD screen from a distance. Second, not all riders own a smartphone or the app to be alerted of the bus’ arrival time. 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 solves those problems. “

In order to build this, we’ve composed the following plan.

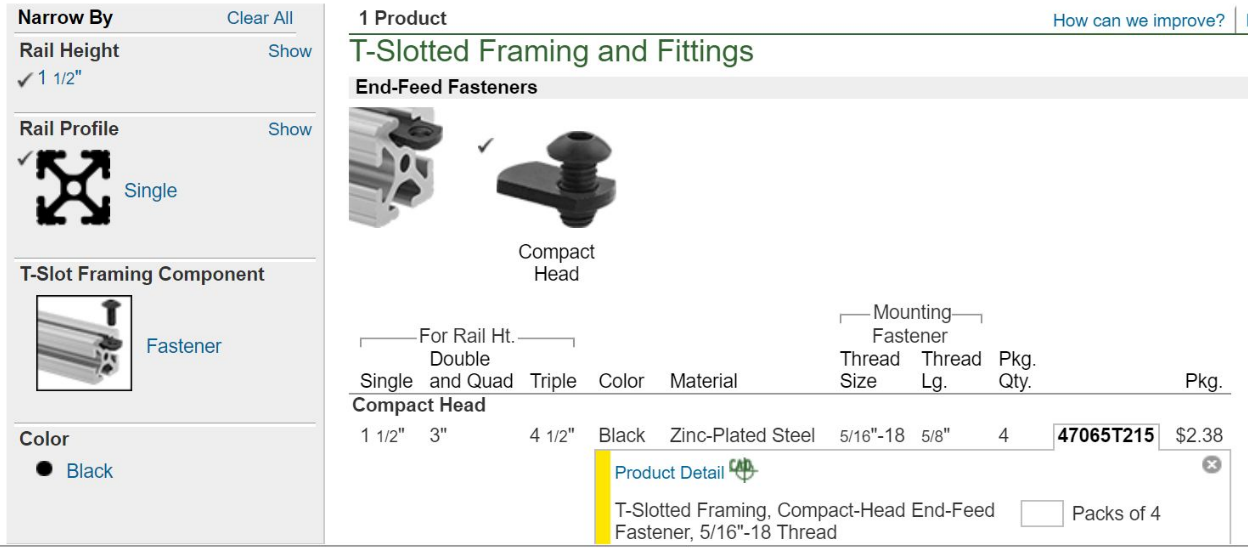


Figure 13: T-Slotted Framing, Compact-Head End-Feed Fastener, 5/16"-18 Thread;
Number of items needed: 18 (each item includes a black screw and a black fastener)
Purpose: To bolt the U-shape Aluminum channels (Figure 14) horizontally onto the T-slot

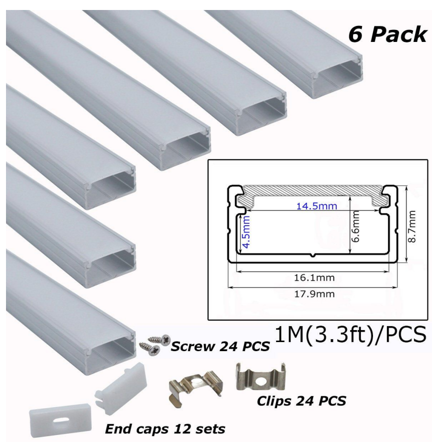


Figure 14: Litever 1-Meter long U Shape Aluminum Channels (for LED strip lights);
Number of items needed: 9 (each item includes an aluminum channel, diffuser and end caps)
Purpose: To protect LED indicator stip lights from weather, hides connecting wires from the public, and diffuses light to give an even glow.

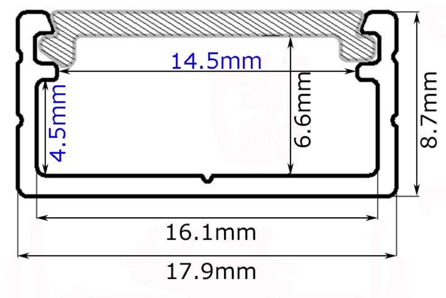


Figure 15: Dimension of U Shape Aluminum Channels
Purpose: 16.1mm is wide enough to fit a 10mm wide LED strip light

Figure 16: 22 Gauge Wire - Four Conductor RGB Power Wire
Purpose: Connecting and lengthening segments of RGB LED Light strips and RGB Controllers

Figure 17: Solderless Clamp On LED Strip Light to Pigtail Adapter - 10mm RGB Strips
Number of items needed: 17
Purpose: Use this solderless adapter to connect your 10-mm RGB LED strip light to 22-18 gauge pigtail power wire. The clear connector easily clamps onto strip ends and pigtail wire without stripping insulation. A secure-snap closure holds wire and strip in place.

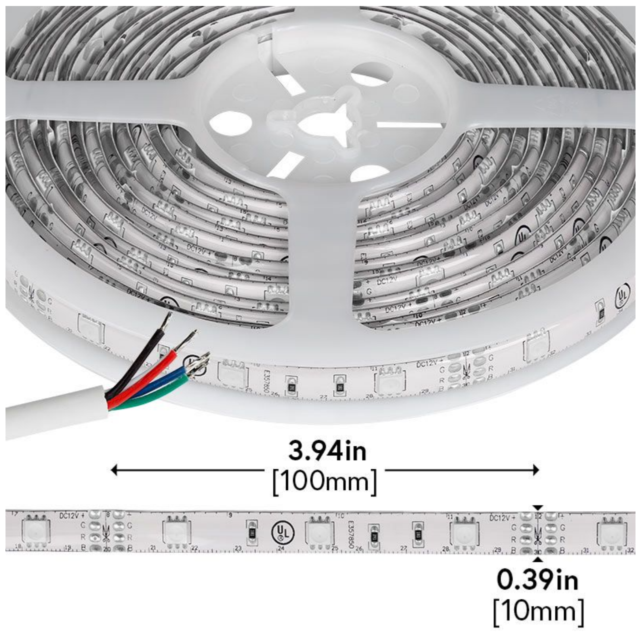


Figure 18: Indicator lights (Outdoor LED Light Strips with RGB LEDs - 63 Lumens/ft)
Number of items needed: 9 (each item is 1 foot long)

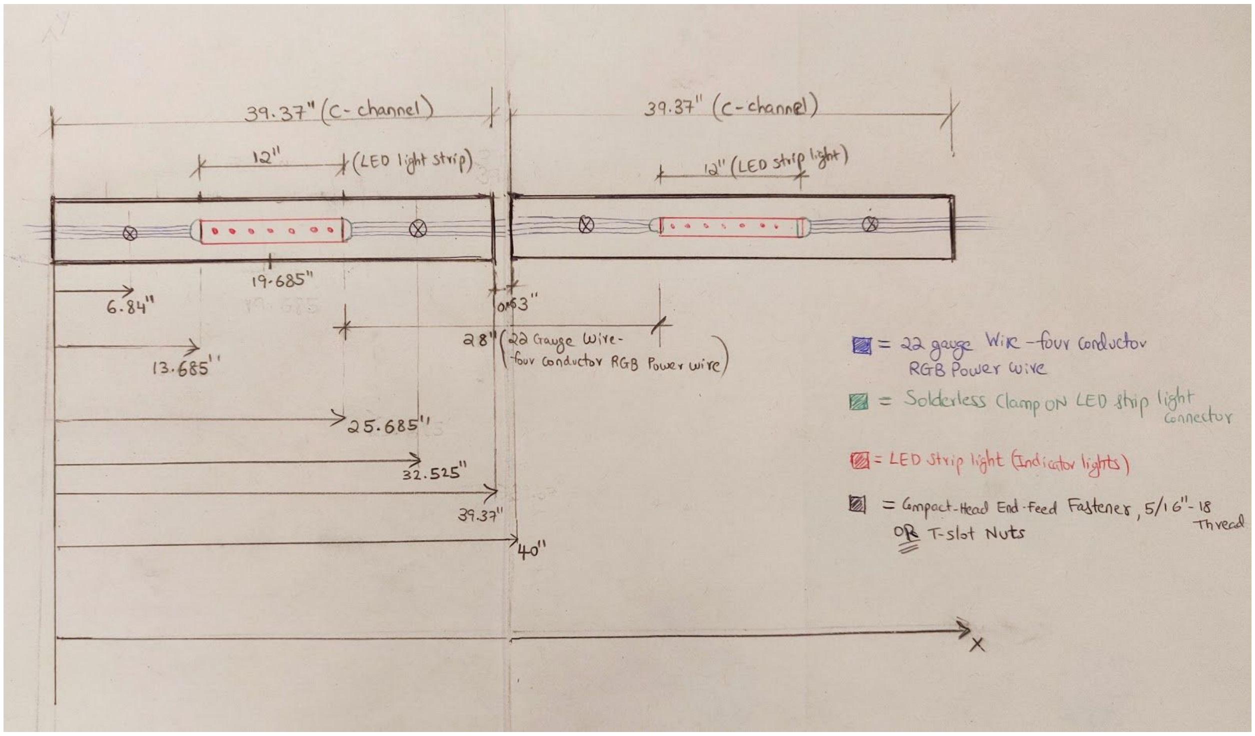


Figure 19: Overview of how the wire connects with each other to power the LED strip light, Manufacturing: Integer line measurements of where the bolts need to be drilled at the C-channel; length of the wires and LED-strip-light; spacing between each C-channel;

Figure 20: Mean Well LED Switching Power Supply - LPV Series 20-100W Single Output LED Power Supply - 12V DC - 60 Watt (with Power Cord)

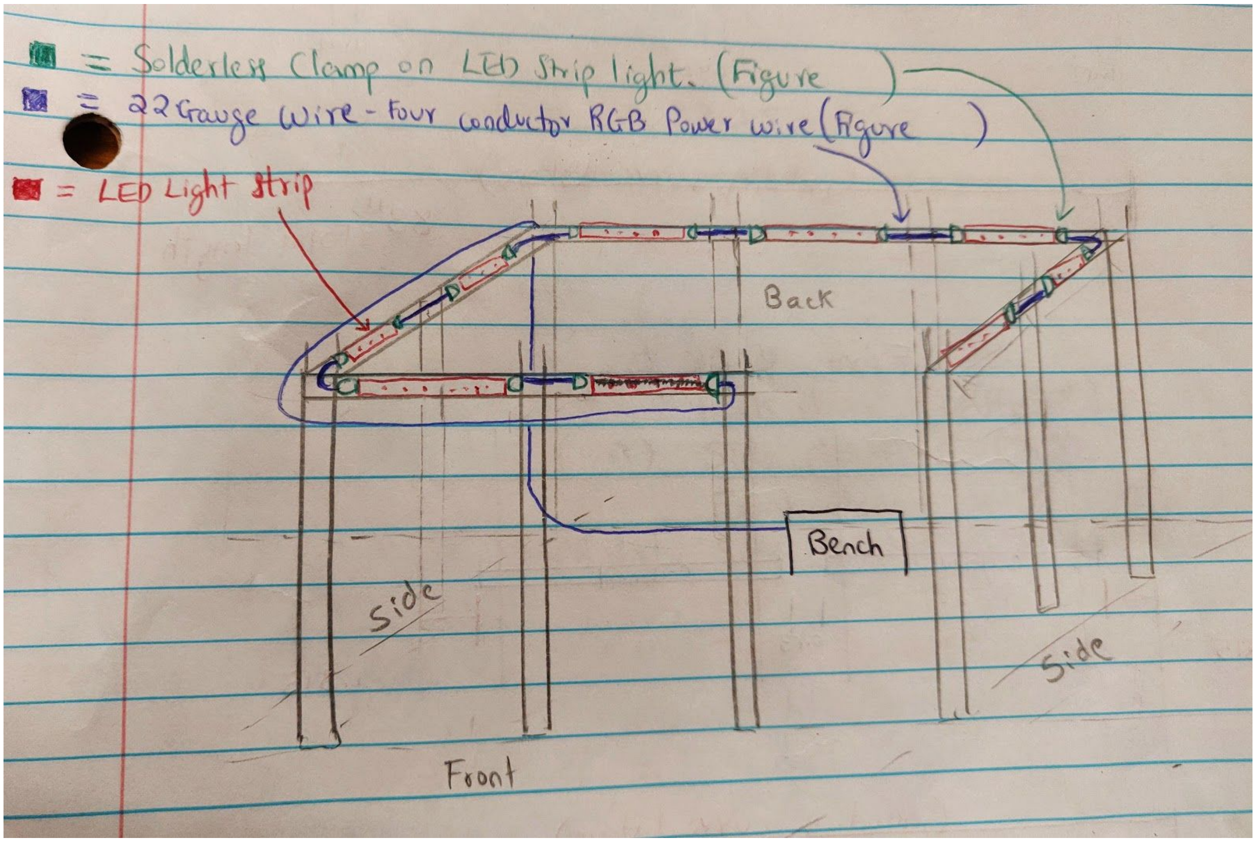


Figure 21: Hand-sketch 3D-drawing of LED-lighting wiring outline

1. Machining of Components:
    a. Starting with aluminum c-channels, we plan on drilling two 5/16'' inches holes at the location specified on (Figure 19).
    b. There will be four L-corner C-channel connectors in total. One of the L-corners will have a 1-inch diameter hole in the center for wires to pass through and enter inside the vertical T-slot post (located at the left-back corner of the bus shelter).
2. Assembly of C-channels (housing for LED indicator strip light):
    a. Place two fasteners/nuts inside the horizontal 1515-S T-slot channel (prior to bolting the 1515-S Tslots to the vertical posts)
    b. Align the 1-meter Aluminum C-channels against the exterior side of the horizontal 1515-S T-slots (see Figure 19).
    c. Insert the screws through the drilled holes of the C-channels and tighten them with the nuts placed inside the 1515-S T-slot channels.
    d. Insert C-channel connectors (Figure 20) with one end to another end of the Aluminum C-channels. Each 1-meter C-channel should be 0.63 inches width apart.
    e. Insert L-connectors (Figure 21) to every four corners of the bus shelter where the C-channel meets.
    f. Repeat steps a-e on every module of the bus shelter. There should be a total of nine modules per medium bus shelter.

3. Assembly of the LED indicator strip light:
    a. Cut the LED-light strip into nine 1-foot long strips. Each strip will have two ends. Clamp those two ends with the “Solderless Clamp On connector” (Figure 17).
    b. Cut the “22 gauge wire-four conductor RGB power wire” (Figure 16) into eight, 28-inches long wires; and one, 200-inches long wire.
    c. Connect the 28-inch long “22 gauge wire-four conductor RGB power wire” (Figure 16) to the “Solderless Clamp On connectors” (Figure 17), which is currently secured to the ends of the LED-strip light.
    d. Peel off the LED-light strip (Figure 18) glue tape and adhere it inside the C-channel (Figure 14) housing.
    e. Connect the 200-inch long “22 gauge wire-four conductor RGB power wire” (Figure 16) to the “final end” of the LED-strip light series, which will need to be connected to a breadboard. The “final end” of the LED-strip light is located at the vertical post next to the entrance (left side) of the bus shelter. This 200 inch long wire will then run back to the vertical post (located at the left-back corner of the bus shelter).
    f. The breadboard should be connected to the power supply (Figure 20) and Raspberry Pi, which would presumably be located inside the bench.
    g. Close the C-channel with the LED-light diffuser (included with the C-channels purchases) to provide a fully enclosed weatherproof housing for the LED-light strip.

Hand Crank Plans

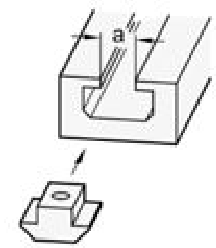
This semester we worked on figuring out the details for our hand crank design: To go along with our sustainable shelter, we brainstormed ideas for fun and easily implementable ideas for other green energy sources. Our favorite power generating accessory idea is the hand crank. It works by Electromagnetic Induction: where a voltage is induced from a changing (moving) magnetic field. Our idea, shown on Figure 14 is to have one or two hand powered cranks attached to the inside of the shelter, which can provide some power to the shelter solely from inputted human work.

We hypothesized that the most fun and effective method to generate the most power would be to introduce an element of competition. Cost permitting, we would like to install two generators side-by-side, which would display the amount of energy produced using a Wattmeter. The results would be displayed either on the Wattmeter, or on the TV. By giving the two participants their respective wattage, we would incentivize the participants to put forth more effort than they originally would have.

1. Machining of Components
    a. Starting with aluminum stock, we plan on cutting out the depth of the housing as specified on the manufacturing drawings. Using a mill, create the 4 holes for the screws to enter on each corner of the housing. Fillet the edges of the outside of the box for safety concerns. Use a drill for the through holes on each side, allowing for the motors shaft and the wiring.

b. The top of the housing is constructed by machining a rectangular piece of aluminum stock.. The edges should be filleted as for the housing, with a radius of 0.1 inch. Threaded-through holes should be created on all four corners just as on the housing.

2. Assembly
    a. To assemble the hand crank, secure the motor in place using the face plate holes. Once the motor is connected to the handle, and the electrical components are in place, secure the top of the housing.



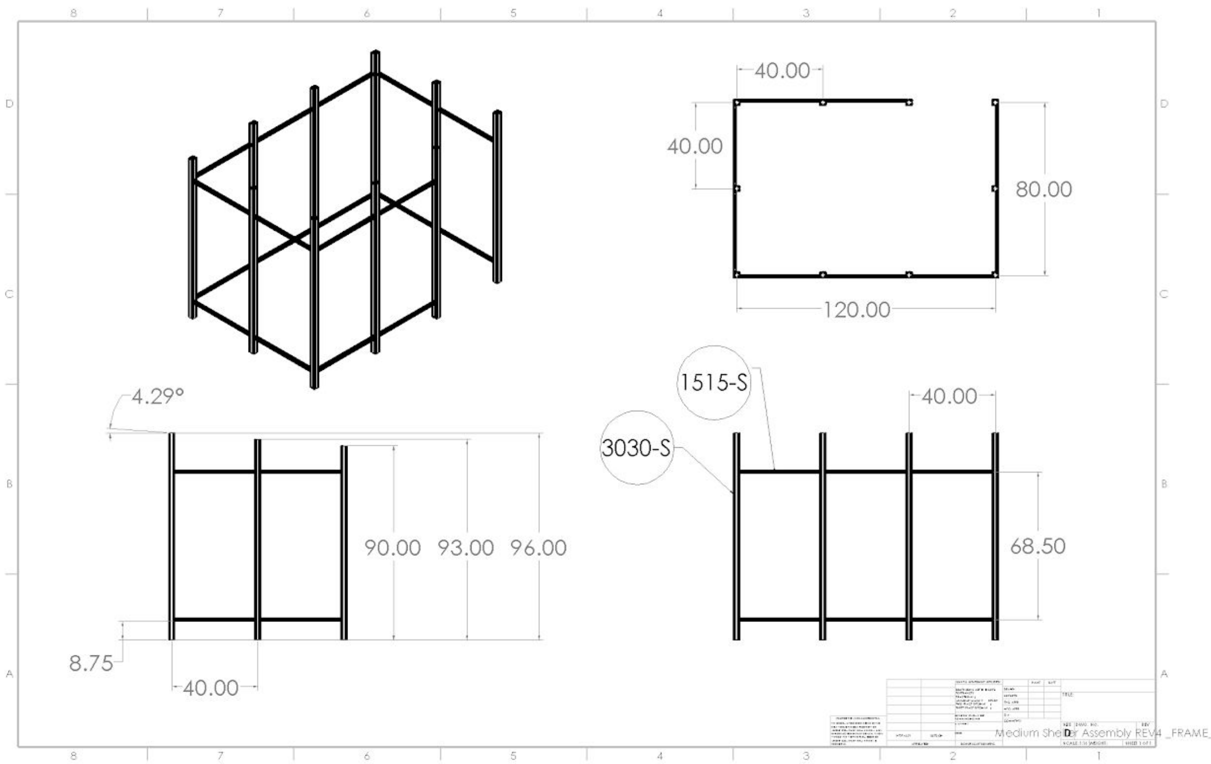
3. Installation onto T-slot
    a. To install the assembled hand crank to the T-Slot posts, we will use up two T-Slot nuts installed from the rear of the housing into the front of each post. This will fix the device in all directions.

Material Details:

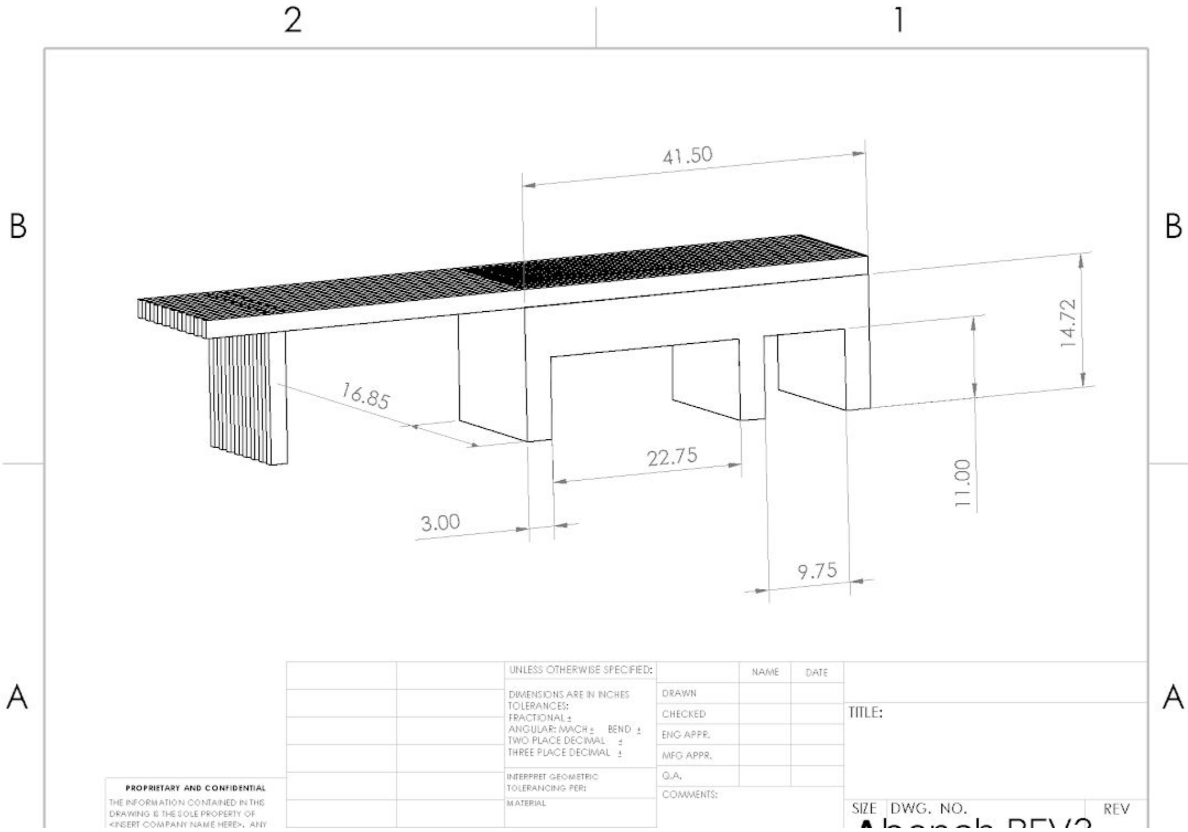
For the creation of the Hand Crank, we plan on using aluminum stock because of its durability, resistance to temperature and weathering, and its overall strength. It is also comparatively cheap and easier to machine than other common materials.

Engineering Drawings

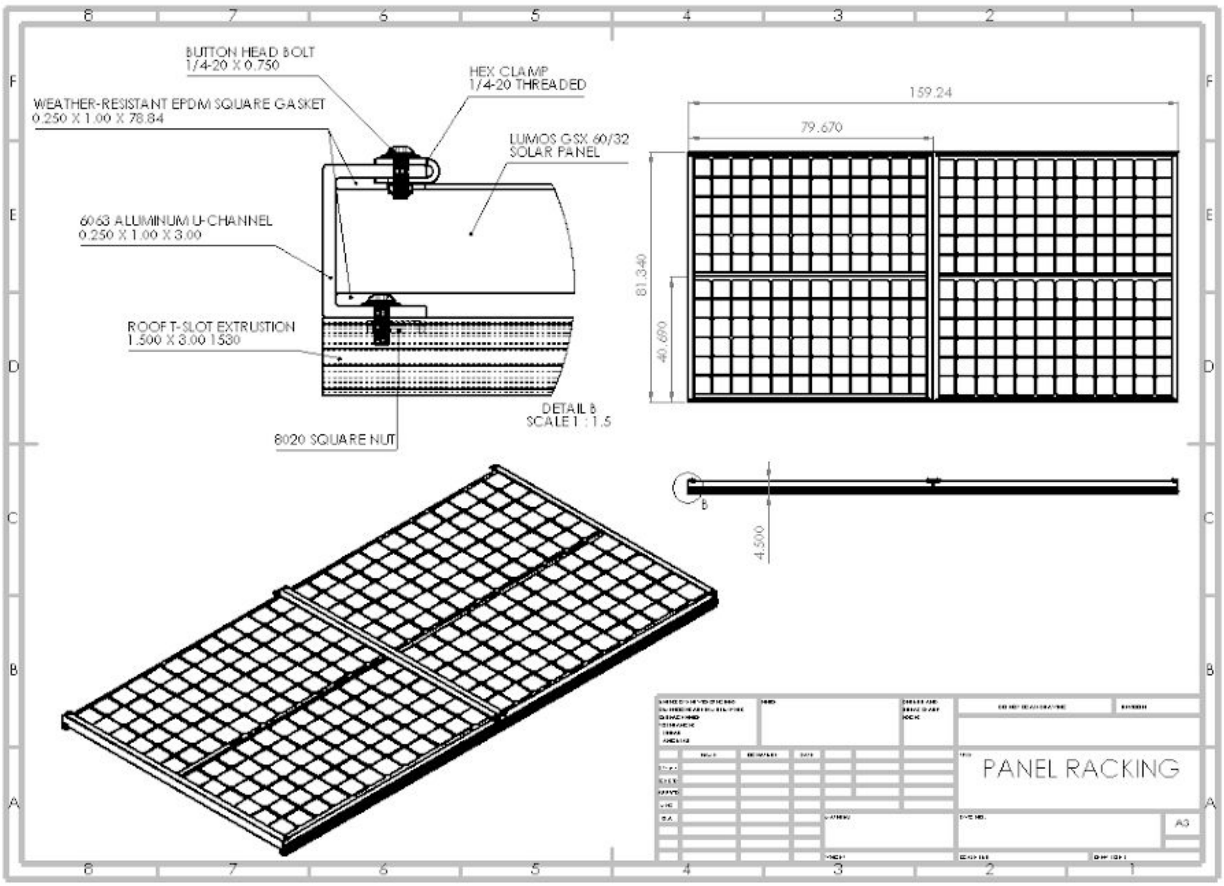
Structural Frame

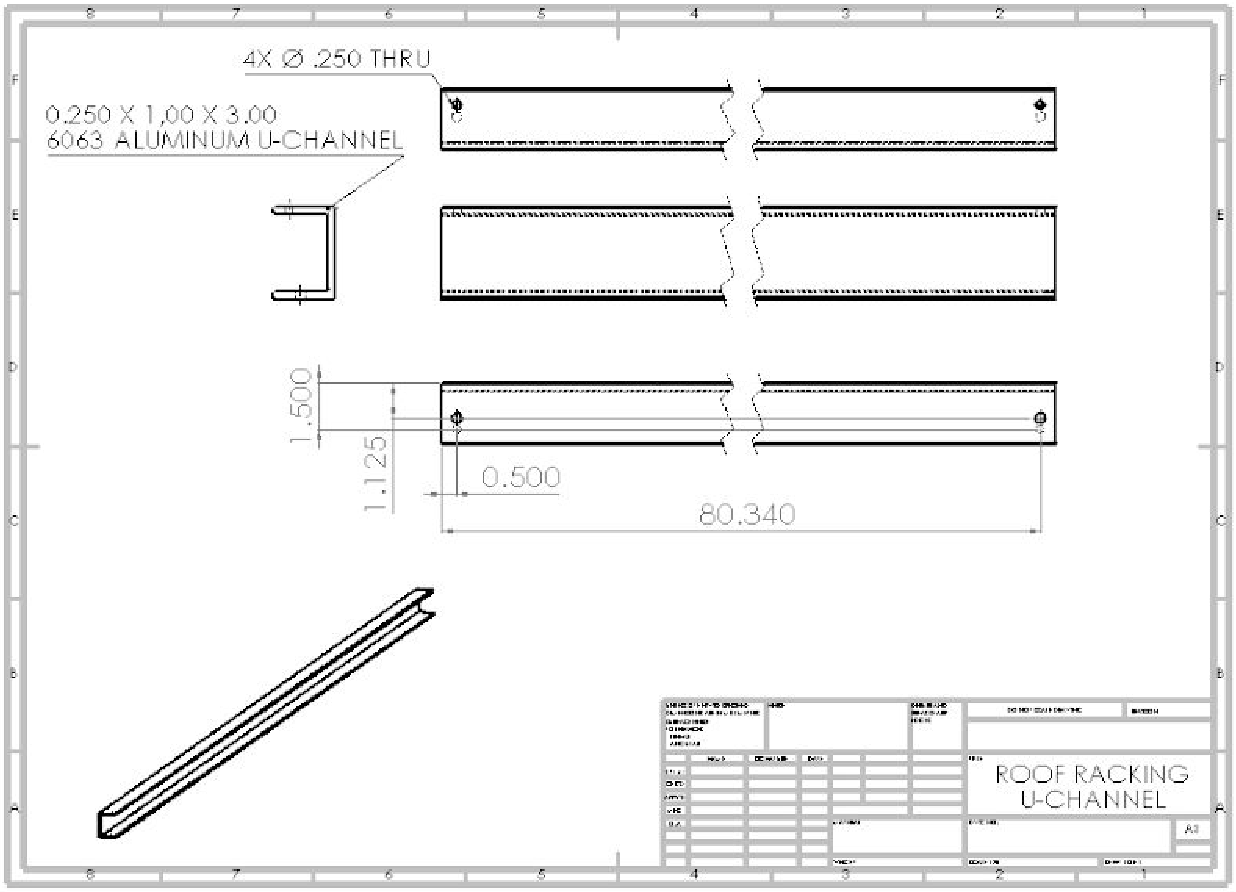


Bench


2
1
B
B
A
A
41.50
14.72
16.85
22.75
11.00
3.00
9.75
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
SIZE
DWG. NO.
REV
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS
DRAWING IS THE SOLE PROPERTY OF
<INSERT COMPANY NAME HERE>. ANY

Roof Racking System

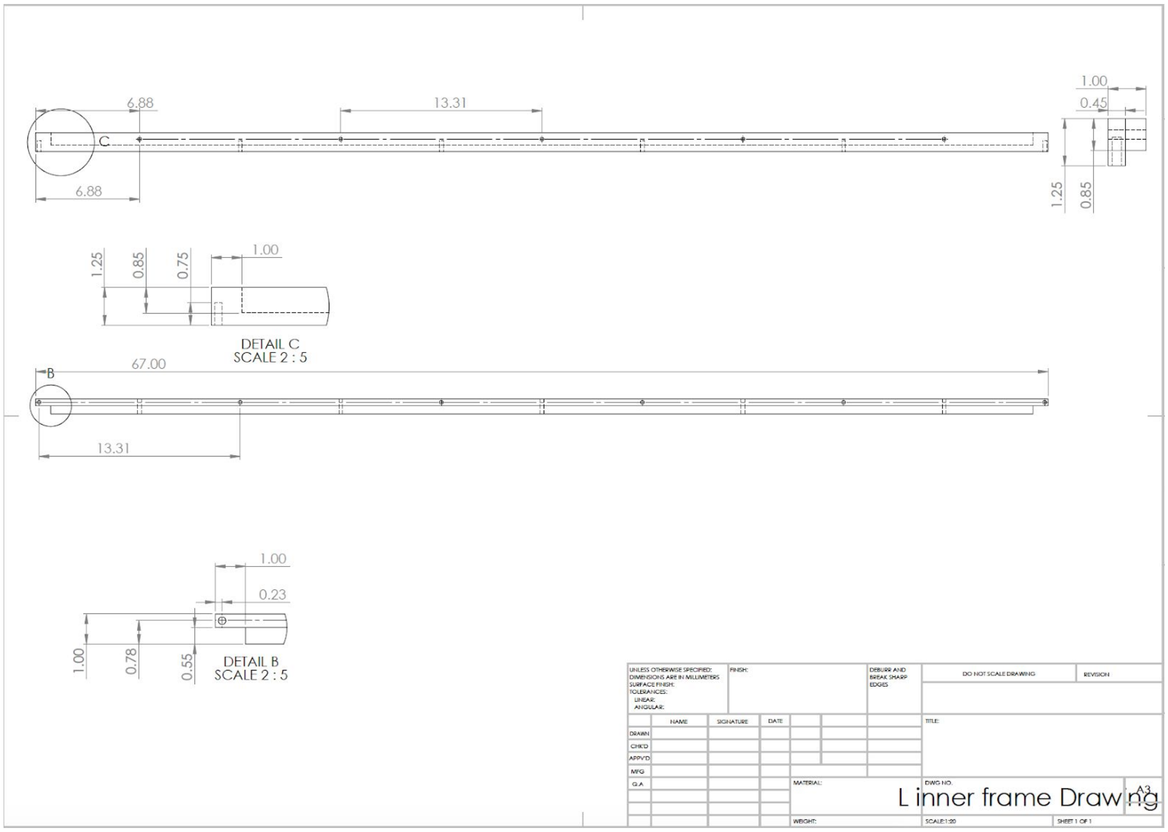



4X Ø .250 THRU
0.250 X 1.00 X 3.00
6063 ALUMINUM U-CHANNEL
1.500
1.125
0.500
80.340
ROOF RACKING
U-CHANNEL

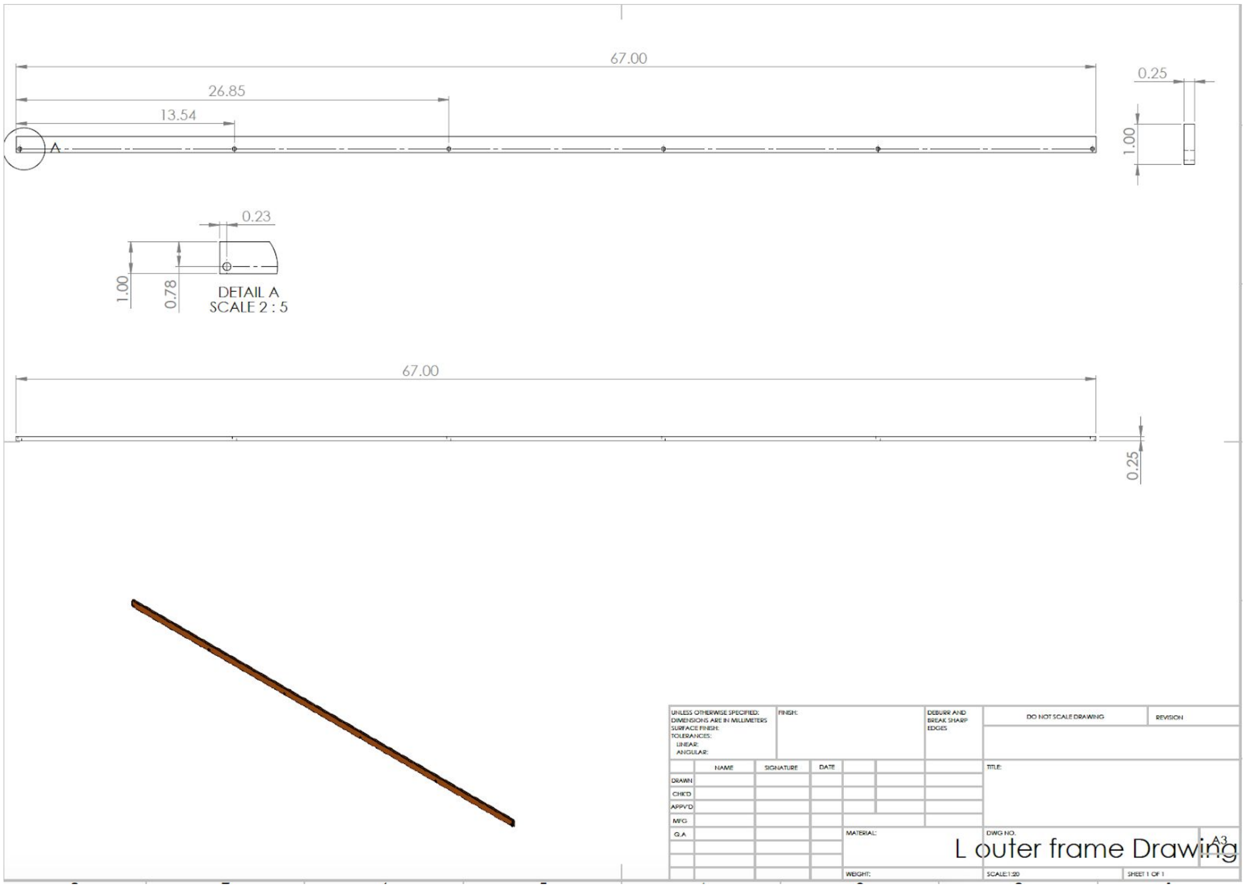
Side Panel Frame

(dimensions in inches)

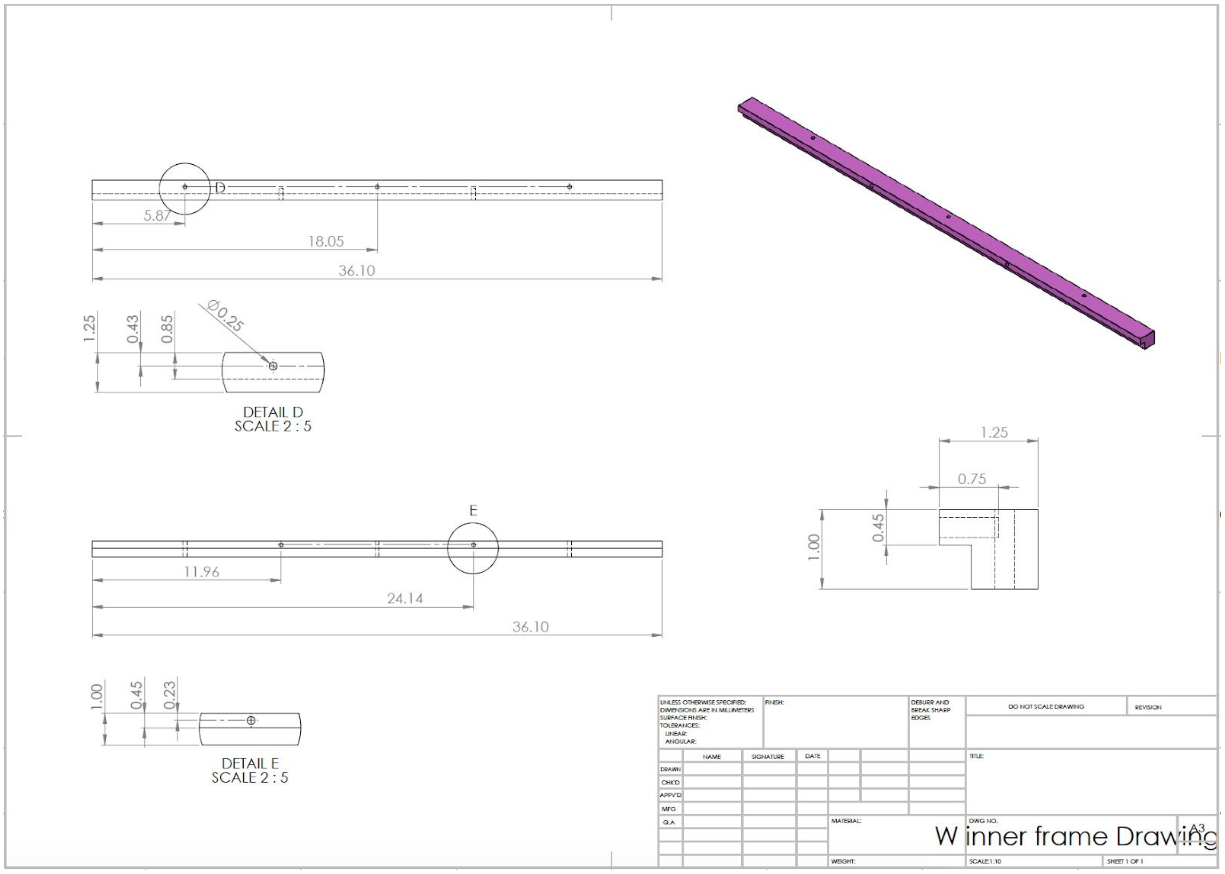
1. Length inner frame



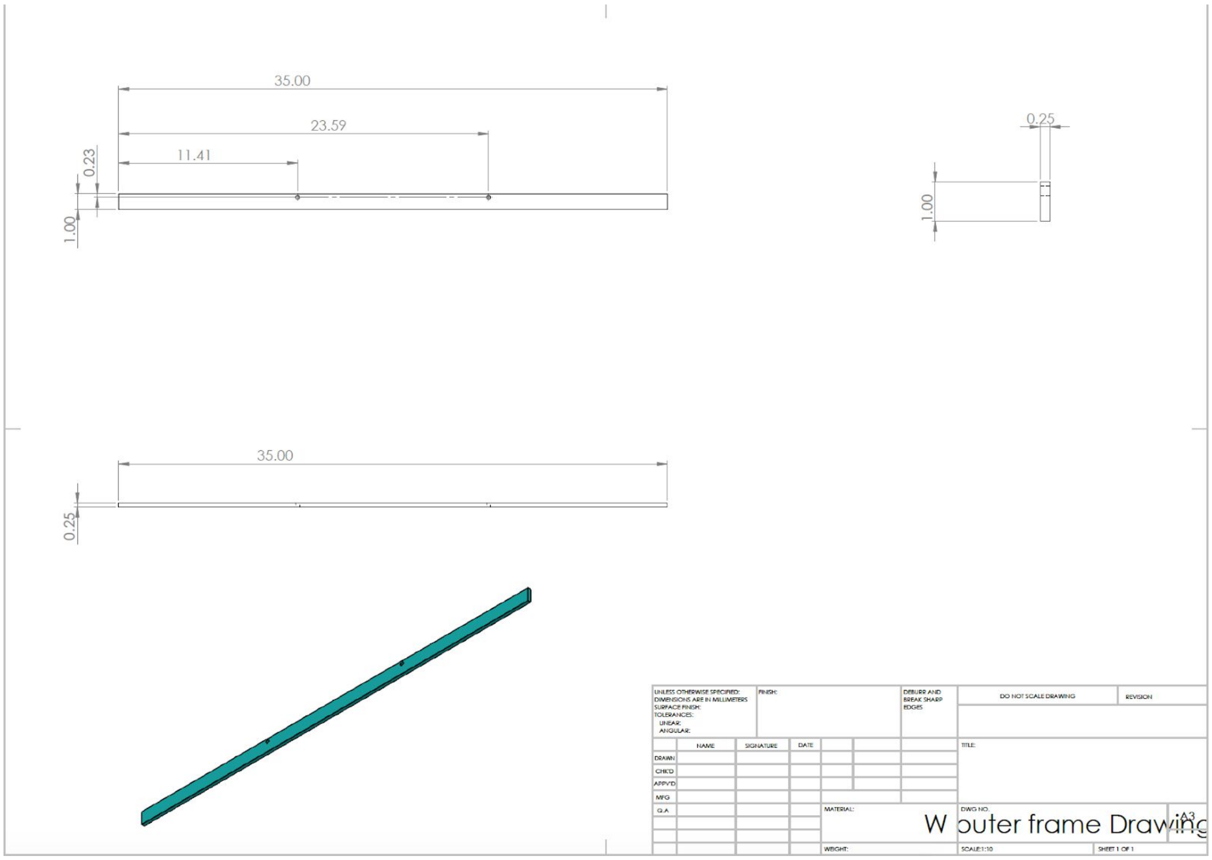
2. Length outer frame



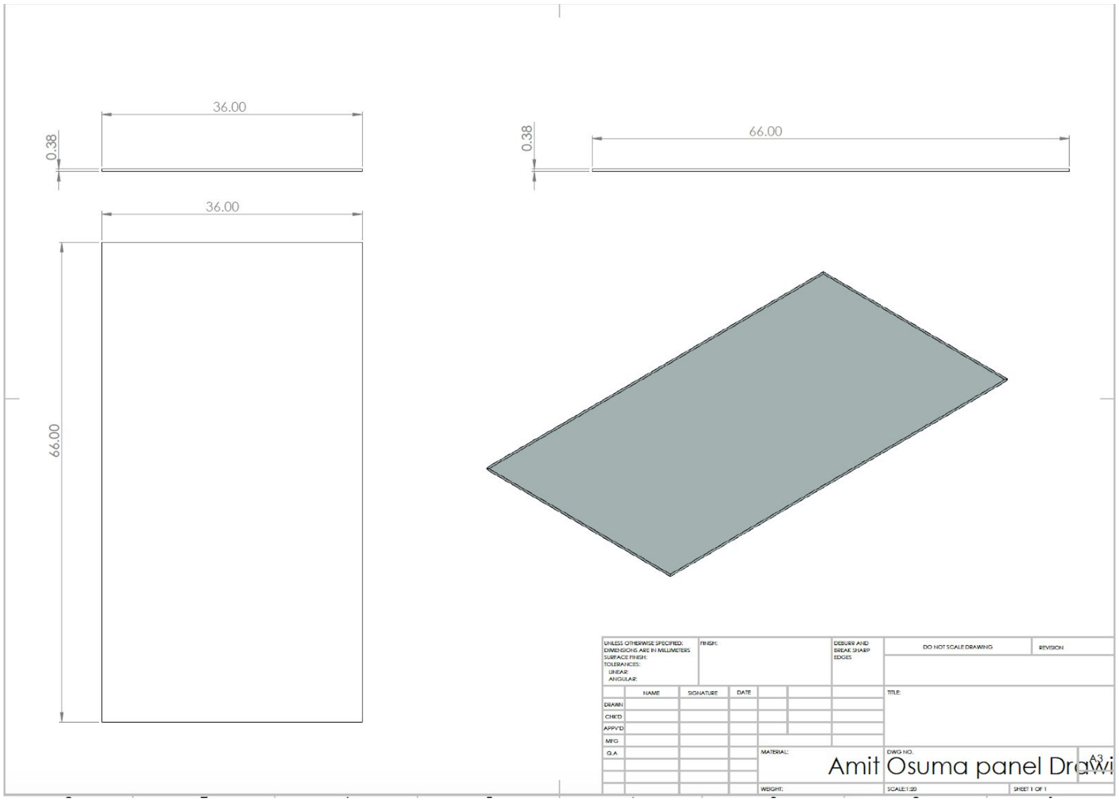
3. Width inner frame



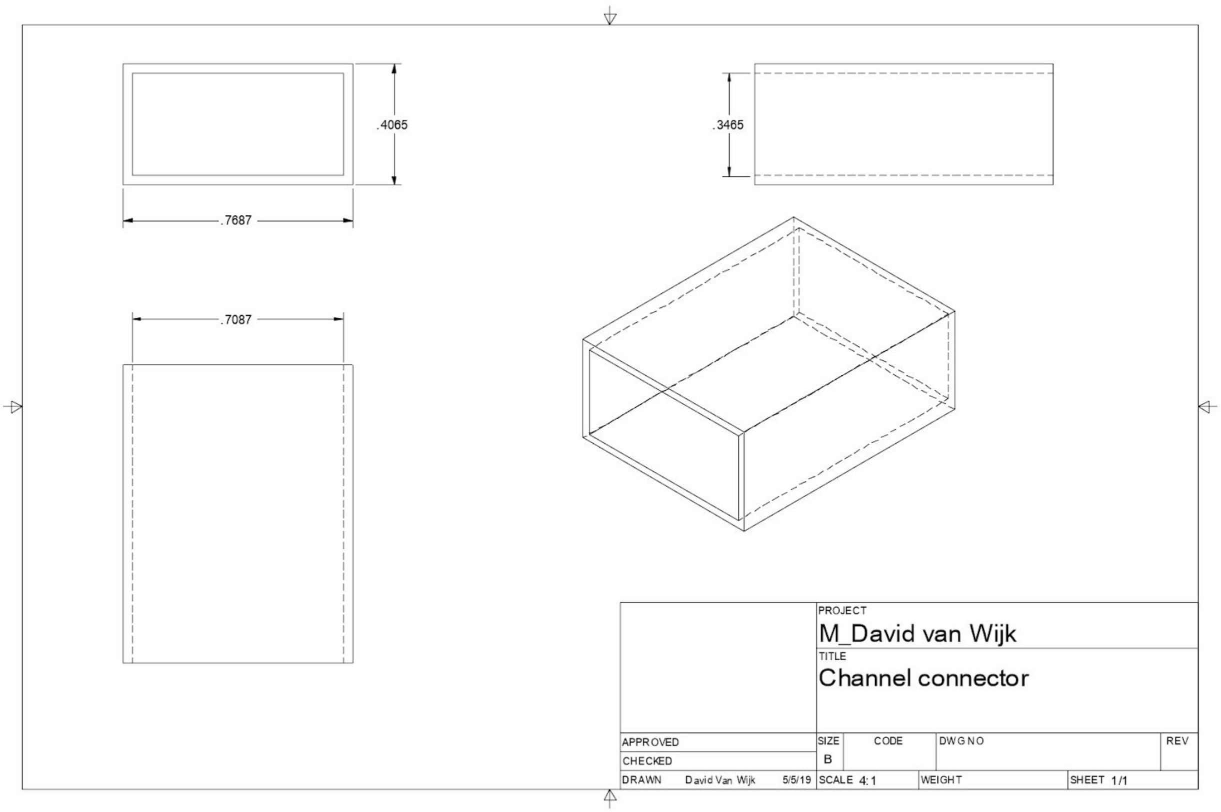
4. Width outer frame



5. Side panel


36.00
0.38
66.00
0.38
36.00
66.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
Amit
DWG NO.
Osuma panel Drawi
A3
WEIGHT:
SCALE:1:20
SHEET 1 OF 1

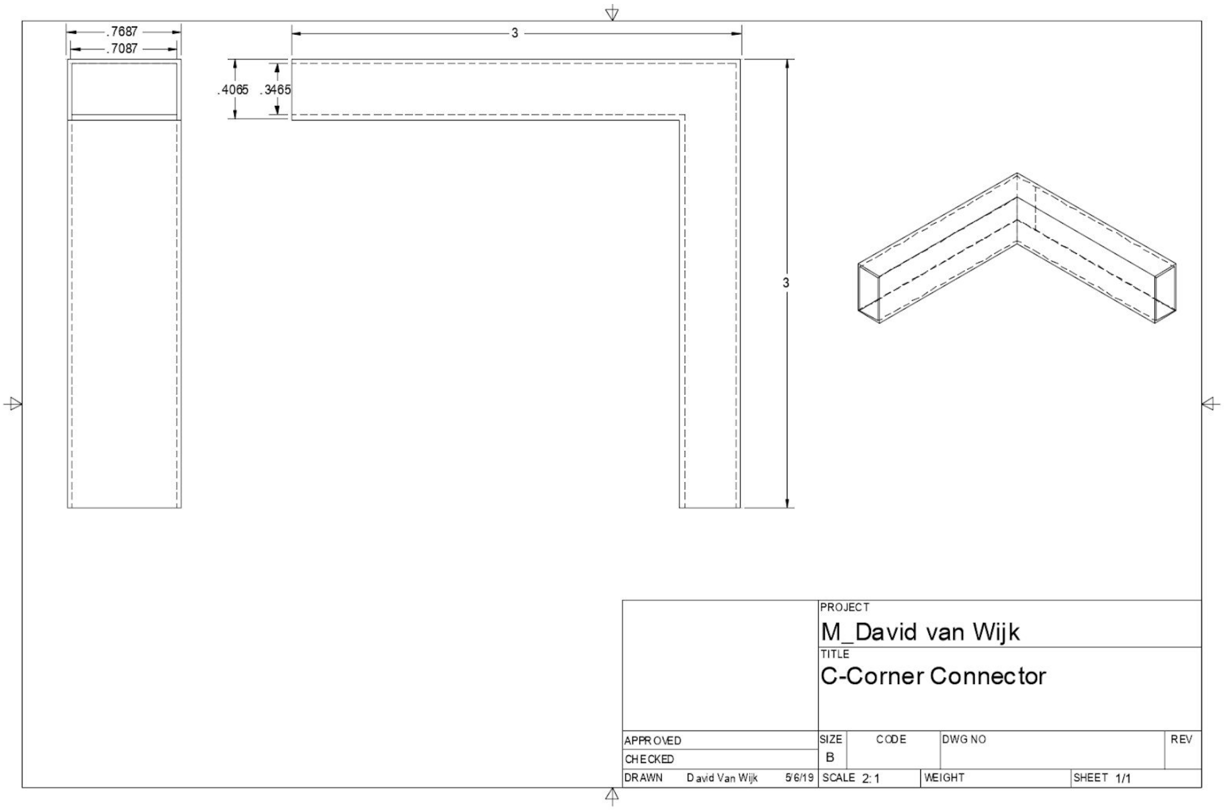
C-Channel (for LED lights) connectors (2.63 inches long)



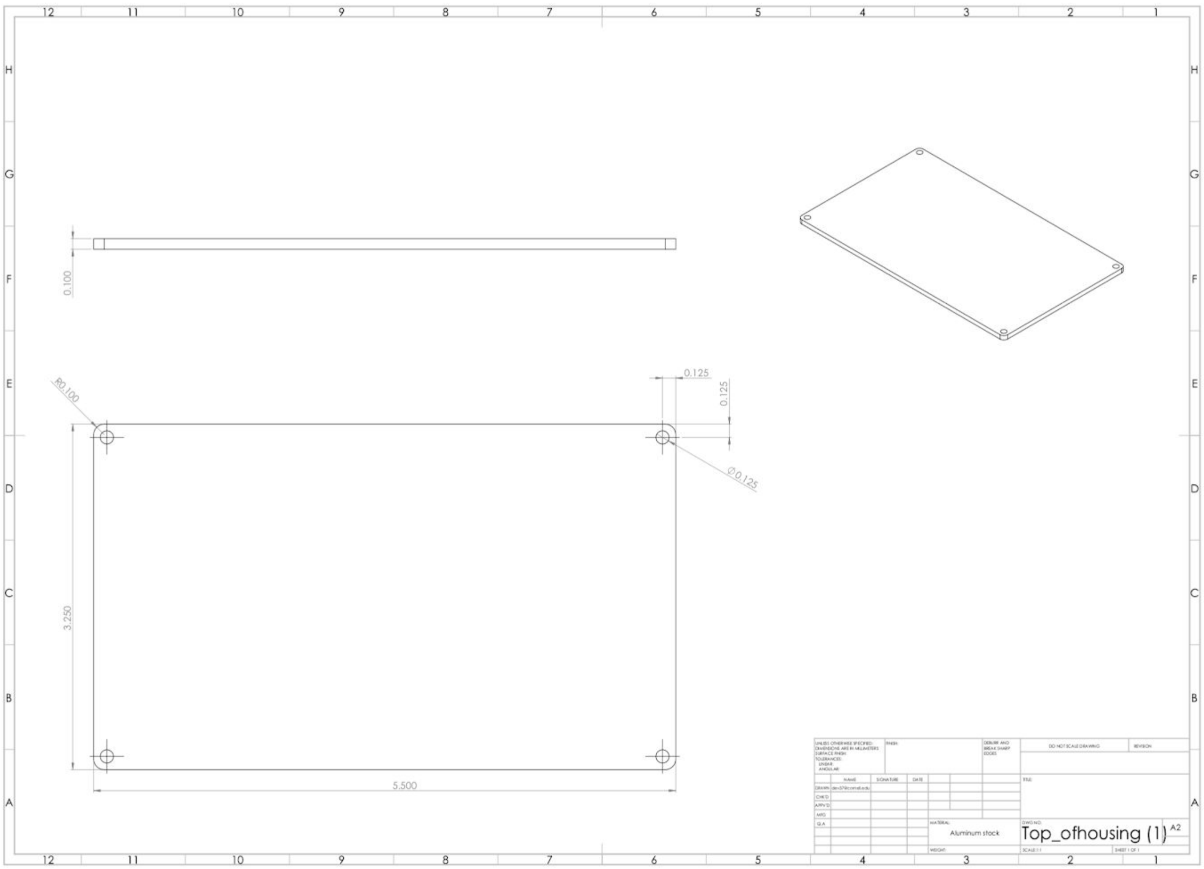
Aluminum C-channel connectors

C-Channel (for LED lights) L-connectors (3 inches long)

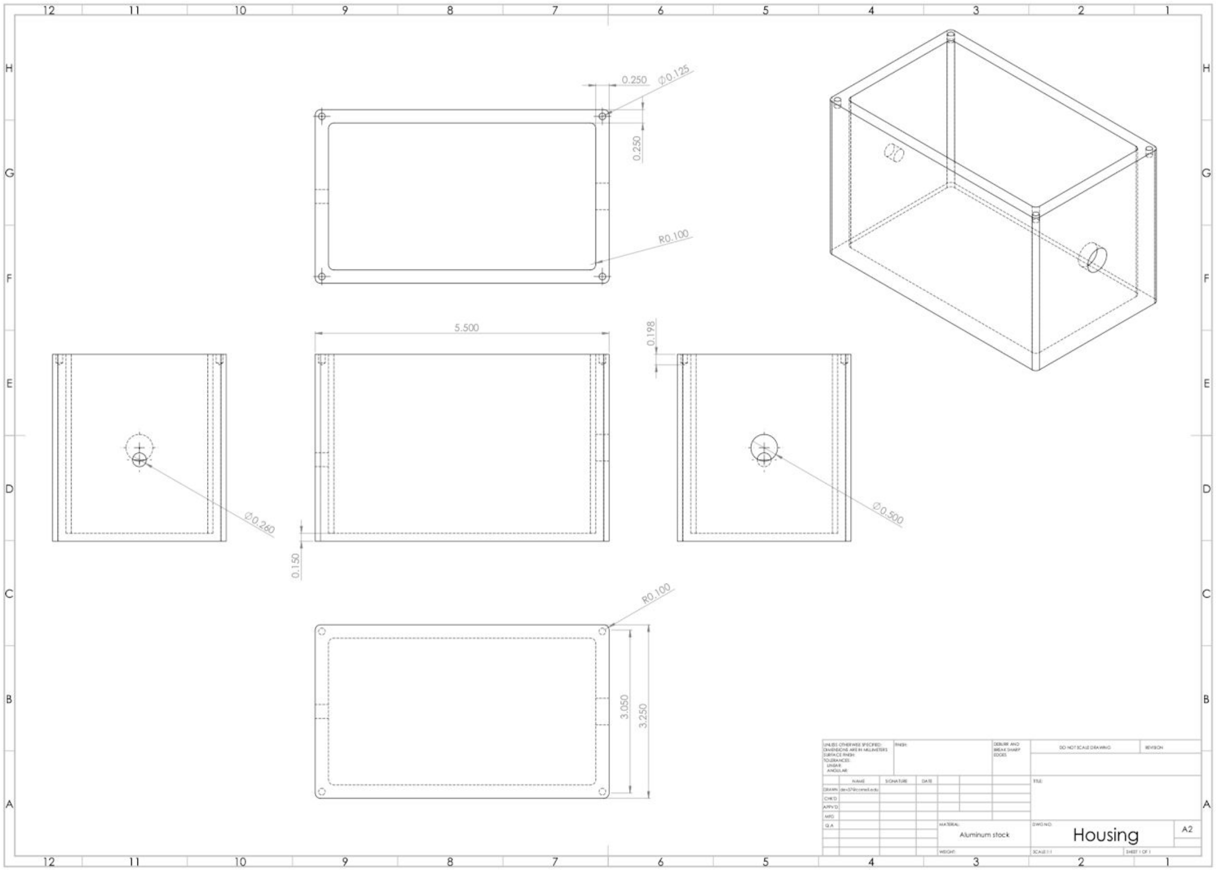
Purpose: Connects multiple 1-meter Aluminum c-channels orthogonally at the bus shelter's four corners.



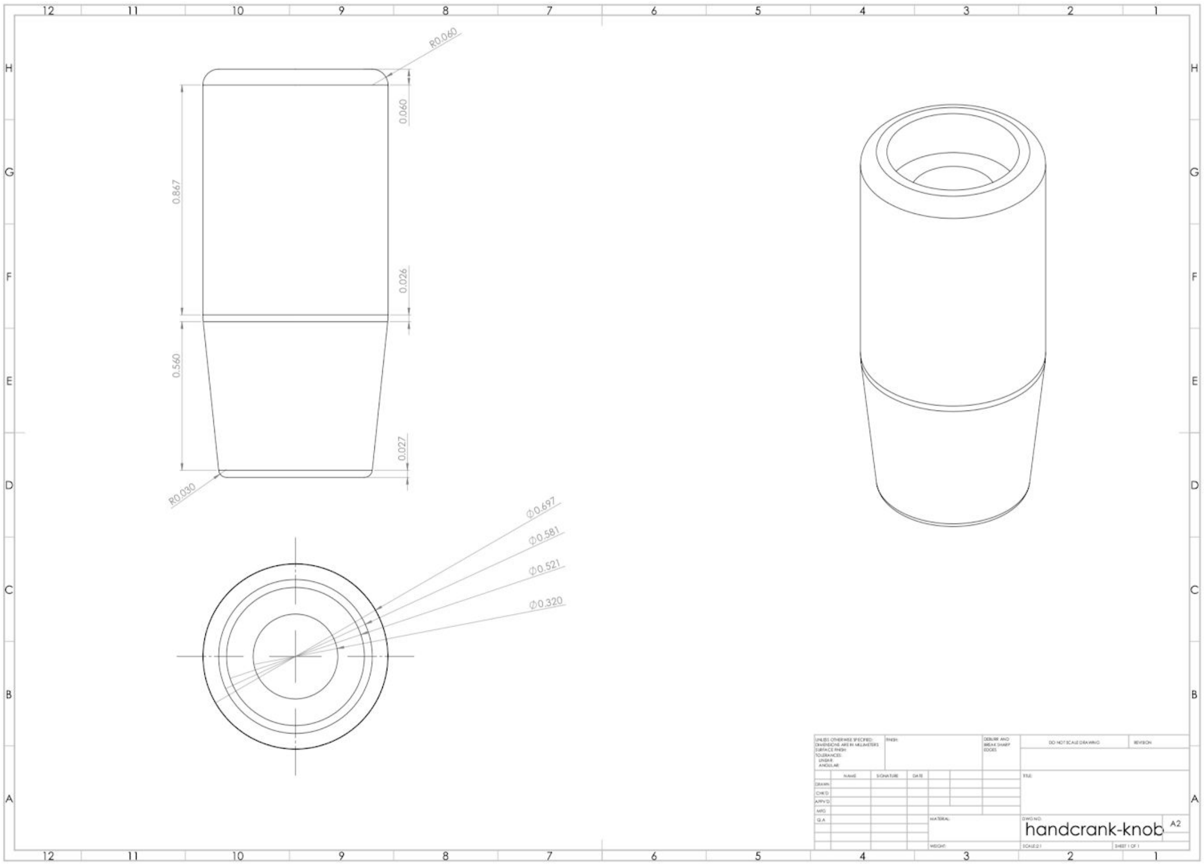
Hand Crank



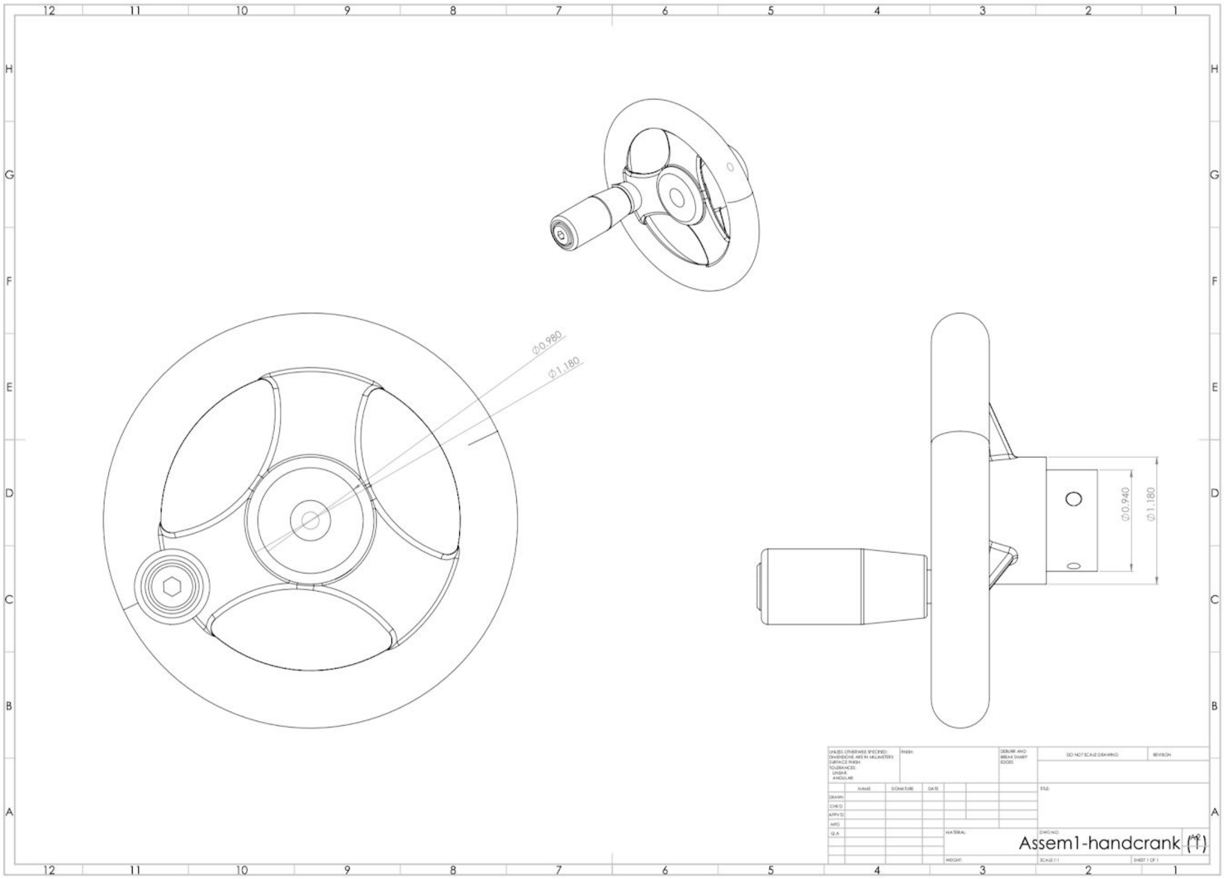
Top of housing


0.250
Ø0.125
0.250
R0.100
5.500
0.198
Ø0.260
Ø0.500
0.150
R0.100
3.050
3.250
Aluminum stock
Housing
A2

Housing



Hand Crank Knob



Wheel Assembly

Bill of Materials

Materials/Parts	Dimensions	Total Units	Cost per unit	Total Cost
Mainframe Components				
15 series - 3"x3" Aluminum T-slot 3030	3"x3"x75"	2	$112.50	$225.00
15 series - 3"x3" Aluminum T-slot 3030	3"x3"x81"	2	$121.50	$243.00
15 series - 3"x3" Aluminum T-slot 3030	3"x3"x84"	4	$126.00	$504.00
Subframe Components (Frame only)				
15 Series 5/16-18 Short Double Anchor Assembly		36	$5.80	$208.80
15 series - 1.5"x1.5" Aluminum T-slot 1515	1.5"x1.5"x37"	18	$19.61	$352.98

Roof Components (Frame Only)				
15 series - 1.5"x3" Aluminum T-Slot 1530	1.5"x3"x118"	4	$109.74	$438.96
15 series - 1.5"x3" Aluminum T-Slot 1530	1.5"x3"x37"	9	$47.26	$425.34
15 series - 1.5"x3" Aluminum T-Slot 1530 (Optional for overhang support)	1.5"x3"x12"	6	$18.81	$112.86
Panel Frame				
6061 Aluminum Bars (1)	1" x 5/16" x 6'	8	$13.86	$110.88
6061 Aluminum Bars (2)	1" x 3/4" x 6'	8	$33.69	$269.52
Roof				
GSX 60/32 Lumos Solar Panels	39.370"x66.929"x1"	1	$308.00	$308.00
Side Panels				
Polycarbonate Sheets (3/8") - ACME Plastics	35"x65"	2	$357.52	$715.04
Hardware Components				
Roof L Bracket fasteners		36	$6.30	$226.80
Electronic Components				
40" LCD screen		1	$250.00	$250.00
Battery Enclosure (PolyCase WQ-76)		2	$160.00	$320.00
LCD Enclosure		1	$588.00	$588.00
300W DC-AC Pure Sine Wave Inverter		1	$154.00	$154.00
Raspberry Pi			$35.00	$0.00
12 Volt 100 ah Lead acid battery (Mighty Max)		1	$174.99	$174.99
Power Cube Adapter		1	$18.99	$18.99
Motion Sensor		1	$49.99	$49.99
8 Gauge Wire (25ft)		1	$18.99	$18.99
10 Gauge Wire (10ft for both red+black)		1	$16.72	$16.72
Connectors for Battery (1/4")		1	$12.95	$12.95
Micro SD with raspbian		1	15	$15.00

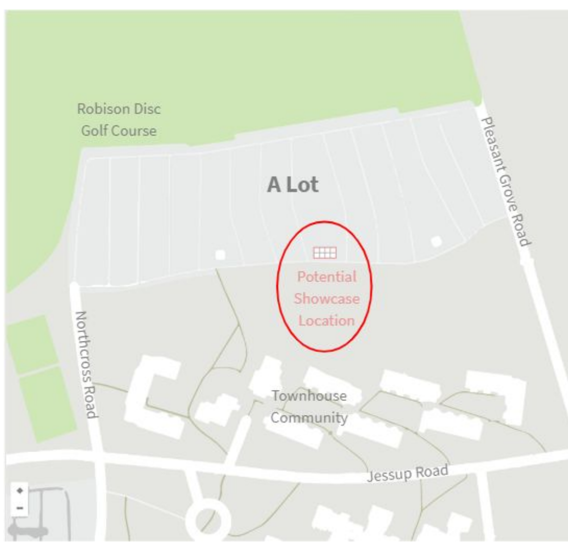
Temperature Sensor		1	3.95	$3.95
DB9/ RJ45 Breakout		1	8.72	$8.72
USB/ rs485 breakout		1	$9.99	$9.99
EPever 12v 24v MPPT charge Controller		1	$159.00	$159.00
Indicator Lights				
22 Gauge Wire - Four Conductor RGB Power Wire		50	$0.29	$14.50
Solderless Clamp On LED Strip Light to Pigtail Adapter		4	$1.49	5.96
CPS-x2ST Standard Barrel Connector		2	$1.95	$3.90
24-18 AWG Wire Splice Connectors -Dual Channel		2	$0.95	$1.90
Mean Well LED Switching Power Supply (WITH POWER CORDS)		1	$29.90	$29.90
Outdoor LED Light Strips with RGB LEDs - 3.28 ft		1	$14.95	$14.95
Litever 6-Pack 3.3ft/1 Meter 9x18mm U Shape Aluminum Channels with Diffuser, End Caps and Mounting Clips LED Strip Channels for Max 16mm Wide LED Lightstrip Light Mounting-LL-007-M		2	$26.99	$53.98
T-Slotted Framing, Compact-Head End-Feed Fastener, 5/16"-18 Thread		5	$2.38	$11.90
Wire Conduit Cover		1	$25.00	$25.00
Bench				
Bench		1	$300.00	$300.00
			TOTAL	**$6,409.46**

This is a basic bill of materials, including the essential pieces needed to build our shelter. It is worth noting that this does not include shipping costs, labor costs, and any other expenses other than material costs. We expect the shelter to cost 2 to 3 times more than on our BOM.

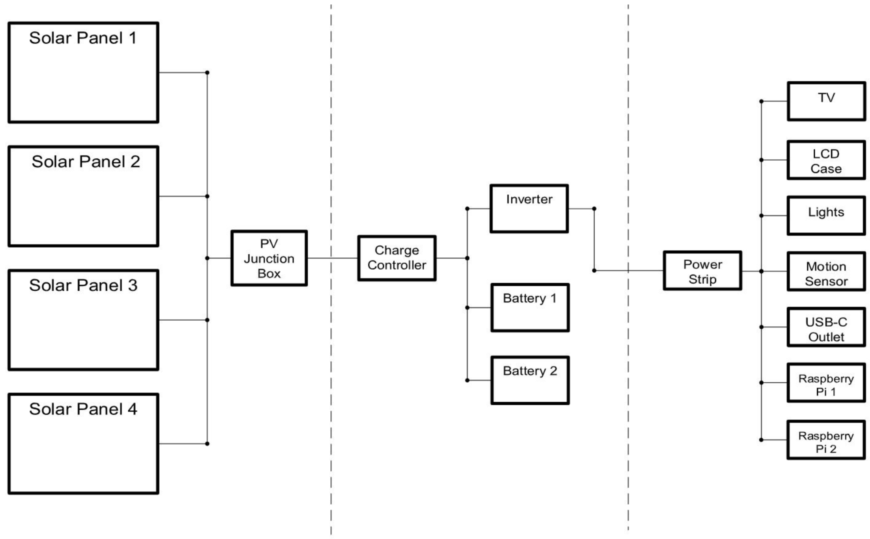
Solar

Introduction

The bus shelters range over a large span of area within Tompkins County with differing variabilities in usage ranging from remote small shelters, medium shelters with occasional usage, and large shelters with frequent usage. TCAT expressed interest in establishing off-grid solar systems at the remote, small bus shelters to provide lighting, since only a small percentage of TCAT's larger shelter models were grid-tied. Cornell students rely heavily on the TCAT transit system, and as a result there are a multitude of bus shelters located on the campus that have a grid-tie already incorporated to provide lighting. With a goal of building our first shelter on Cornell's campus, our team began to develop a showcase version of our shelter which would implement a larger solar panel system to promote both Cornell and TCAT's image of sustainability, as well as powering additional appliances such as an LCD display. The current solar system package will be utilized for both the medium and large shelters as an off-grid setup. The proposed location for the first bus shelter is at A-Lot with the accommodating site map below.



Load Diagram



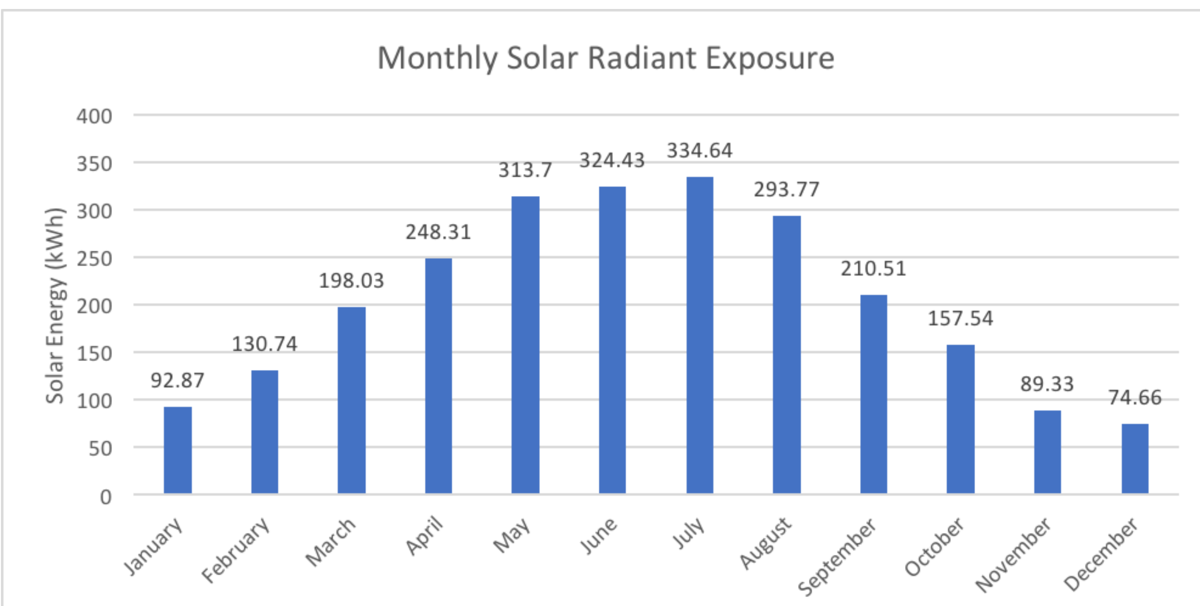
The shelter is to have four standard Lumos Solar GSX 72/72 BiFi panels that serve as a roof and a solar panel for the shelter with a rated power of 360W, peak power voltage of 38.6V, short circuit current of 9.99A, and module efficiency of 17.9%. The solar panels would be joined in parallel to a PV junction box, which would then feed into a 45A rated MPPT charge controller. The charge controller will control charging for the 100ah 12V sealed lead acid batteries in parallel, thereby giving an overall capacity of 200ah at 12V. The inverter will convert the 12V DC to 120V AC in order to charge a power strip which will be responsible for delivering power to the loads.

In analyzing the components that require power, an estimated worst and average case time-on for each load is determined. A Wifi Router is assumed to not be needed due nearby hotspot connections therefore this load is listed with 0 W. The worst case and average case times assumed are estimations of the time the listed device will be on. When solving the solar calculations, the worst case is assumed to design for a more robust system. These times can most likely be reduced further with the application of the motion sensor controlling the loads to turn on only when people are in the shelter, or to turn off non-essential components when the battery levels are low.

Max Loads (per day)					
Medium & Large	Watts	Time Assumed (hr) WORST CASE	Time Assumed (hr) AVERAGE CASE	Loads in Wh WORST CASE	Loads in Wh AVERAGE CASE
LCD TV	8	12	8	96	64
LCD Enclosure	8	24	24	192	192
Indicator Lights	13.5	8	6	108	81
Interior Lights (on at night)	9	6	5	54	45
Motion Sensor	7	24	21	168	147
Charging Outlet	20	2	0.5	40	10
1x Rasberry Pi's	10	24	24	240	240
Wifi Router	0	24	24	0	0
Total	75.5	-	-	898	779
30% Energy Loss	-	-	-	269.4	233.7
Total with loss	-	-	-	**1167.4**	**1012.7**

Solar Calculations

Solar projections for the A-Lot location of the bus shelter can be determined by using the software Rhino and Grasshopper for simulation. The bus shelter was simulated at the proposed A-Lot location with a 4.5 degree roof pitch facing North. The amount of solar radiant exposure to the roof is modelled and averaged per month, and then extrapolated by multiplying by the efficiency and number of panels.



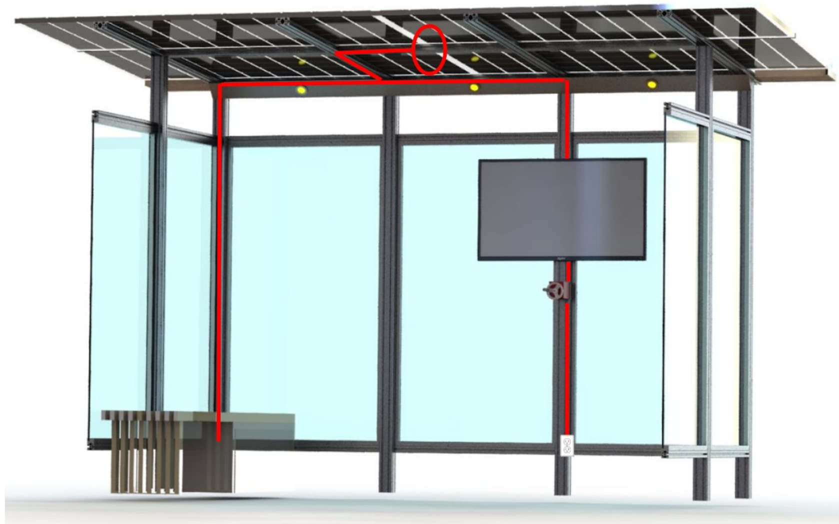
The daily load energy usage was previously determined to be 1167.4 Wh in the worst case scenario estimation, and can be used to solve for the daily net energy production for the shelter to validate if the shelter can sustain the loads at its orientation. Based on the simulation and projections, the shelter is expected to be energy positive and able to consistently charge the battery. This procedure can be applied to other potential bus shelter renovation locations to determine the feasibility of solar panels. The same simulation can be ran with the shelter oriented, and the loads at each shelter should remain constant.

The batteries aligned in parallel can give an overall capacity of 200ah at 12V, and the loads can be divided by 12V to determine the needed amp-hour capacity for the loads for a total of 97.28ah which is then accommodated for a 15% battery loss and 60% depth of discharge for a needed capacity of 190.5ah. This means the shelter can last approximately 1 day without any solar radiant exposure and worst case load usage.

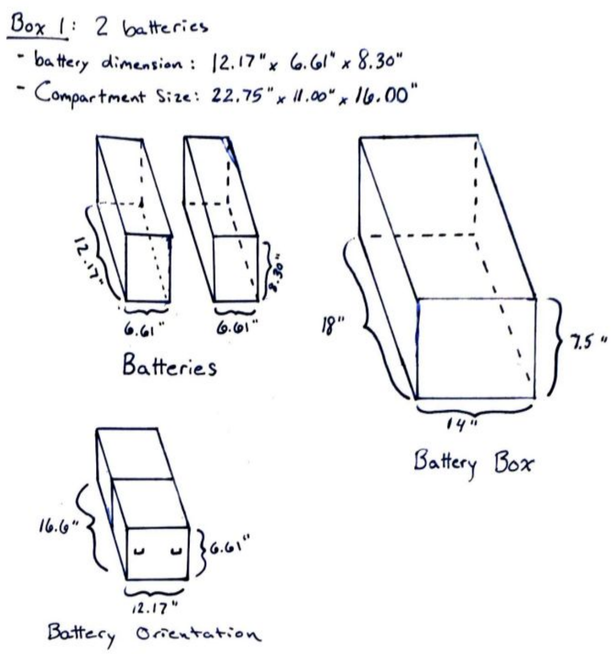
Month	Total Energy Produced (kWh)	Net (kWh) - Worst Case
January	2.144997419	0.7838974194
February	3.019672258	1.658572258
March	4.573854194	3.212754194
April	5.73516	4.37406
May	7.245458065	5.884358065
June	7.493286452	6.132186452
July	7.729104516	6.368004516
August	6.785139355	5.424039355
September	4.862101935	3.501001935
October	3.638665806	2.277565806
November	2.063234839	0.7021348387
December	1.724405161	0.3633051613

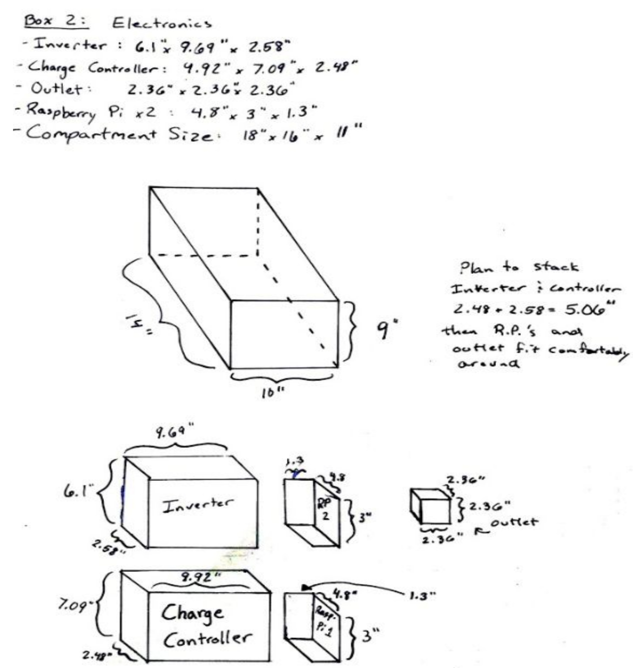
Wiring

The Lumos solar panels are aligned on the roof, so the positive and ground terminal connectors can be routed directly to the horizontal roof beam into the light bar. The light bar is a new design concept that is a hollow triangular bar with one light per module that provides efficient and concealed routing of wires. The light bar allows access to the vertical T-slot posts that provides for routing the bench through the back left post when facing the shelter and the LCD screen. The shelter can be modified with its placement of the hand crank, USB-C charging outlet and LCD display since the light bar gives direct access to any vertical T-slot post towards the back of the shelter. The picture below illustrates the sample wire runs by the ‘red line’ with the connection starting from the battery, routing up to the light bar, and then distributing to the solar panels and the LCD display.



Electronics Storage Within Bench





The battery storage compartment, pictured above left, contains two 12V, 100Ah sealed lead-acid batteries. The nature of sealed lead acid batteries allows for the configuration shown. Placing the batteries bottom to bottom is the most efficient use of the limited space beneath the bench, and should allow for easy access to all wires. Pictured above right is the electronics box, which houses the inverter, charge controller, power strip, and a singular raspberry pi. With the newest iteration of the bench design and current list of components, there will be more than enough room to house all of these parts in a variety of different configurations.

Digital

Introduction

This semester we set out to finalize the implementation for a system we have been envisioning for 2 years. The challenges we faced in previous semesters, most notably with the serial communication interface that should allow us to read solar charge from the solar panel controller, informed our goals for this semester.

To meet our goals we needed to build on our team from last semester by recruiting students whose strengths would allow us to reach our deliverables faster. We brought on Krithik Ranjan, a freshman electrical engineer with a strong background in microcontrollers to dive deep into the communication protocol between our raspberry pi and solar charge controller, debugging what in previous has been a problematic subsystem. Additionally we recruited Peter Kaplinsky, another impressive freshman with a background in programming, to write the system that would process and store the solar analytics from the shelter. Our returning UX designer Kamille Gomez rounded out the team, focusing on creating and validating the designs of the screen that displays relevant information to bus riders.

The most notable goals that we met are:

- finalizing an initial UX design for bus arrival info screen and validating design
- implementing the design in code with live bus data
- building a backend to store solar analytics data
- updating to a more modern and robust charge controller

The goals we failed to meet

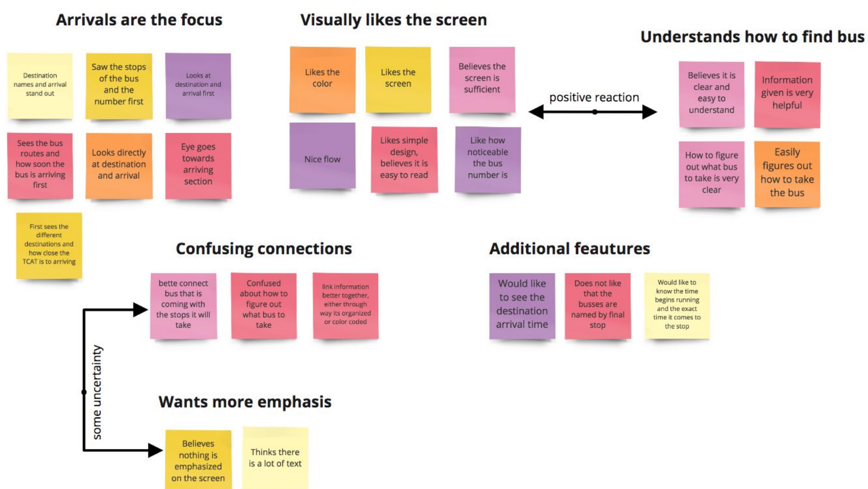
- building a robust and easily reproducible connection between charge controller and raspberry pi
- physically prototyping entire digital system

UX + Display

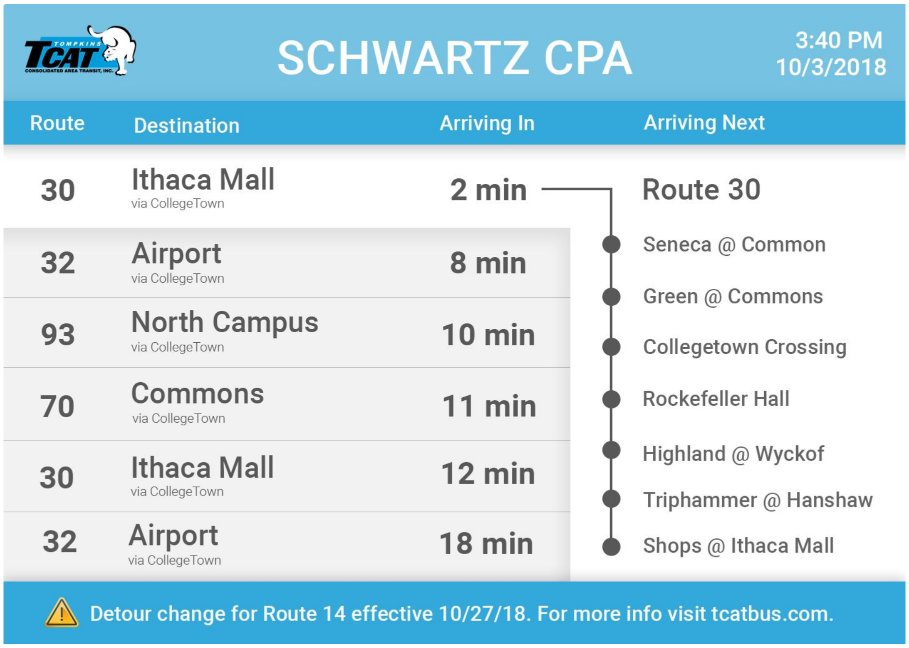
After the completion of a second design iteration of the information display, user testing was done. The goal of user testing was to see if riders understood the information presented to them and to see if the current information given fit the mental model of what riders need when taking the bus. 11 participants were surveyed to indicate their feelings about the current screen design. Out of these participants 4 had lived in Ithaca for a time period of 4 years, 1 for 3.5

years, 1 for 3 years, 1 for 2.5 years, 2 for 2 years and 1 for 1 year. All participants were students at Cornell University and identified as bus users.

Testing results showed an overall positive response to the second iteration design. An affinity diagram was used to analyze the data collected. The first theme identified in the affinity diagram was a focus on arrival. The majority of participants indicated that the arrival section was the first part of the screen brought to their attention when looked at. This fits a design goal the team had when designing the screen. The second theme identified was an overall visual liking of the screen layout and design. Participants liked how the screen looked and thought of it as visually appealing. This relates the third theme identified that overall participants understood how to find the bus they needed. The fourth theme found is that participants found some connections confusing. This relates to the fifth theme that participants want more emphasis on certain aspects. It was found that the portion of the screen that displays ll of the stops of the arriving bus was disconnected from that buss's arrival information. These two themes are what steered the direction of the design of the third iteration.



The display screen was redesigned to better connect the arriving bus with its stops. This was done by changing the color of the arriving next section. The arriving next section is now connected to the bus it corresponds to. The hope is that this emphasizes the connection in the user's mind. Other minor adjustments were made to make the screen more visually appealing, such as changing the color for the alert and adjusting text size. Now that a third iteration is complete, the next step is to set up the display in a shelter and do empathy field testing to see how participants feel with this screen actually implemented.



Software

Backend

In order to store the solar power data provided by the raspberry pi controller, a database was needed. Using python, we created a program that received JSONs containing information about the output of the solar panels and stored them in a database. To implement the database, we used MongoDB. The schema for the database is such that inside each JSON data point are nested key-value pairs, containing information on the time the reading was taken, the solar power generated that day, and the carbon dioxide emissions prevented by the solar panels. When input to the database, each data point is paired with a unique identifier so that it could be easily retrieved for analysis or display in the future. This database was paired with a simple website, where the individual solar panel data can be retrieved. With Flask, we developed a simple website that receives solar panel data and adds it to the MongoDB database. Moreover, should users like to see the data, it can be accessed through the website.

CUSD Team Member 2/8/19

Emissions Collection Data

{"battery_percent": "76", "coal_burned": {"units": "lbs", "value": "81.4"}, "daytime": "true", "gasoline_consumed": {"units": "gallons", "value": "8.4"}, "power_generated_day": {"units": "KWH", "value": "1"}, "power_generated_month": {"units": "KWH", "value": "30"}, "power_generated_year": {"units": "KWH", "value": "360"}, "power_used_day": {"units": "KWH", "value": "2"}, "power_used_month": {"units": "KWH", "value": "15"}, "power_used_year": {"units": "KWH", "value": "300"}, "timestamp": "2012-04-23T18:25:43.511Z", "total_CO2_emissions_saved": {"units": "lbs", "value": "40"}}

Frontend

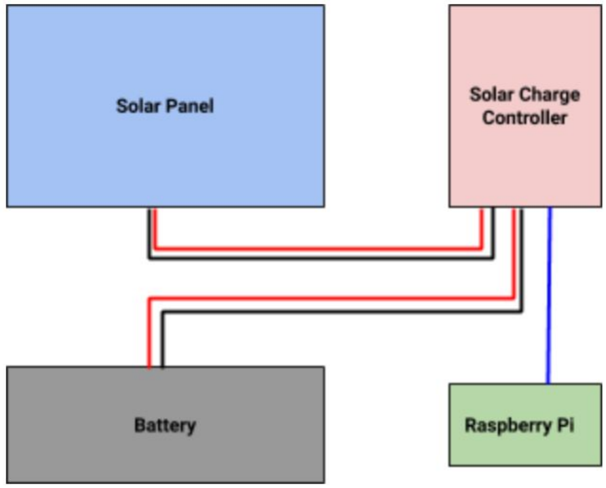
While the design of the bus arrivals screen was well-engineered, it was limited to displaying arrivals for one stop. Moreover, the header could not be changed, and the same bus stop name was always displayed, even if the arrivals data were for a different stop. To fix this problem, two key functions were implemented: a function to update a live clock using AM/PM times and a function to ensure that the data being displayed is specific to a given bus stop. This adds modularity to the bus screen by allowing the same code to be used for any bus shelter, requiring only that the stop code be changed.

Hardware

Solar Analytics

This section of the Digital subteam is to regulate and monitor the power generated by the solar panels on top of the shelter to be stored in the battery pack. It is done using a Solar Charge Controller. The type of solar charge controller being used is called MPPT (Maximum Power Point Tracking) that ensure that a minimum amount of solar energy is wasted.

We aim to monitor and record the power being generated by the solar panels by the solar charge controller itself, by communicating with it in real-time through a Raspberry Pi. Majority of this semester has been spent on trying to find the best solar charge controller in terms of ease and reliability of this communication. General connections of a solar charge controller with other components present in the system are as shown in the wiring diagram.



The options for solar charge controllers studied over this semester are given as follows:

1. **EPEVER Tracer-BN (https://www.epsolarpv.com/product/61.html)**
   a. RS485 Communication protocol (primitive)
   b. Incompatible with Raspberry Pi
   c. Software provided for Windows by manufacturer non-functional
   d. ~$150

2. **Renogy Rover Li (https://www.renogy.com/rover-li-40-amp-mppt-solar-charge-controller/)**
   a. Current solar charge controller
   b. RS232 Communication protocol (Serial, easier to communicate with)

c. Testing yet to be done
d. ~$170

Challenge

The major challenge faced is the fact that most solar charge controllers sold in the market aren't meant to be used as a power monitoring system, hence the feature is not made user-friendly enough to use in a complete system.

Alternative

If unable to establish reliable communication with any solar charge controller in the future, another way the solar output and power saved can be monitored through external sensors like wattmeter, voltmeter, ammeter, all connected to the Raspberry Pi.

Masterplan

Introduction

Previous Work

In the Fall of 2018, TCAT approached us with a unique issue. They had no formal database or spreadsheet of information for existing shelters located throughout Tompkins County. Such a database would be critical not only to TCAT for their existing shelters, but to the Sustainable Mobility team in our search for a suitable location for our own student designed shelter. Thus, the Sustainable Mobility Masterplan team was formed to manage this problem.

In its first semester, the Masterplan team sought to develop a preliminary spreadsheet that would identify the relevant stakeholders to each stop in Ithaca, such as precise location and type of property where the shelter was located. They also took pictures and observations on the condition of the shelters within the City of Ithaca. Finally, the team gathered ridership data from September 2018 for these shelters. The team then analyzed all of this information using a systems engineering approach to create a prototype spreadsheet.

Spring 2019

This semester, we set out to expand on that previous work. While the scope of the prototype spreadsheet was impressive, we decided to scale back some of the information and focus on a select subset of shelters, so that we could create our own prototype and present it to TCAT. While we initially decided to analyze shelters in and around Cornell, we were eventually able to exceed that goal and expand to the stops in and around Cornell as well. To do this, we modeled our spreadsheet off the prototype from the previous semester. The old prototype had great background information, but we wanted to have the complete situation report of each shelter, so that a user of this spreadsheet could fully understand the state of the shelter without actually being there.

System Tools

The Masterplan team created the database by walking around campus and the surrounding area and making observations on the stops and shelters. Based on the data the team received, the team used system tools to analyze the system. Specifically, the team used Analytical Hierarchy Process (AHP) and Decision Matrix to assist with decision making. First, the team classified the stops into two groups: stops with shelters and stops without shelters. For the stops with shelters, the system tools were used to decide which shelters needed to be replaced by a new shelter or removed. For the stops without shelters, the team used the system tools to decide where a new shelter should be built.

Stops with Shelters

For the stops with shelters, the team came up with nine requirements that the shelters should meet by observing the performance of the riders in those stops, as well as personal experiences and interactions with the shelters. They are shown in the table below:

REQUIREMENTS
Make the size/capacity of the shelter suitable.
Make the construction materials as optimal as possible.
Maximize the number of routes.
Make the aesthetic condition as optimal as possible.
Make the structural integrity as optimal as possible.
Make the functionality as optimal as possible.
Make the shelter have lights during the night.
Make the shelter keep out the wind/rain/snow.
Make the shelter have seats for passengers.

Then, the team used AHP to calculate the weight of each requirement. The team first classified these requirements into three groups: Make the Shelter Useful, Make the Shelter User Friendly and Other Qualities. Next, the team weighted each group. After that, the team assigned a weight for each requirement in each group. The final weight of each requirement is the product of group weight and the requirement weight in the groups.

Make the shelter useful		Make the shelter user friendly			Other Qualities			
0.4		0.35			0.25			
Make the shelter keep out the wind/rain/ snow.	Make the ridership as high as possible.	Make the functionality as optimal as possible.	Make the shelter have seats for passengers.	Make the shelter have lights during the night.	Make the construction materials as optimal as possible.	Make the aesthetic condition as optimal as possible.	Make the structural integrity as optimal as possible.	Make the size/capacity of the shelter suitable.
0.5	0.5							
		0.4	0.3	0.3				
					0.25	0.25	0.25	0.25
0.2	0.2	0.14	0.105	0.105	0.0625	0.0625	0.0625	0.0625

For each requirement, the team gave a standard as to how the shelters can be rated based on these requirements. The details are shown below:

Size	Suitable	Unsuitable	Very Unsuitable
	0.7	0.2	0.1
Construction Materials	Very Good	Good	Poor
	0.5	0.3	0.2
Route Numbers	Many	Normal	Few
	0.5	0.35	0.15
Aesthetic Conditions	Very Good	Good	Poor
	0.5	0.3	0.2
Structural Integrity	Very Good	Good	Poor
	0.5	0.3	0.2
Functionality	Very Good	Good	Poor
	0.5	0.3	0.2
Light	Yes	No	
	0.8	0.2	
Keep Warm Inside	Very Good	Good	Poor
	0.5	0.3	0.2
Seats	More seats	Less seats	No Seats
	0.6	0.3	0.1

For instance, for Size, the team would rate a shelter as 0.7 if the size is suitable, 0.2 if the size is unsuitable and 0.1 if the size is very unsuitable. Suitable means that the size of the shelter matches the level of usage of the shelter. For example, if the ridership of this stop is high, and the size of the shelter is large, we evaluated the shelter as suitable; if the size is medium and the ridership is high, we evaluated the shelter as unsuitable; if the size is small and ridership is high, evaluated the shelter as very unsuitable. Similarly, the standard of each requirement was created, shown below:

Stop Number	Stop Name	Size	Construction Materials	Current Routes	Aesthetic Condition	Structural Integrity	Functionality/Ease of Use	Light	Ability to Keep Warm Inside	Seats	Total Score	Percentage
1353	A Lot - Lower Stop	0.2	0.5	0.15	0.2	0.2	0.2	0.8	0.5	0.6	0.37375	67.40%
1351	A Lot - Upper Stop	0.1	0.3	0.15	0.2	0.2	0.2	0.8	0.5	0.6	0.3275	59.06%
1330	Appel Commons	0.2	0.5	0.15	0.3	0.3	0.3	0.8	0.2	0.3	0.35	63.12%
1544	Bradfield Hall	0.7	0.5	0.35	0.3	0.3	0.3	0.8	0.2	0.3	0.42125	75.97%
1545	Bradfield Hall across street	0.7	0.5	0.5	0.3	0.3	0.3	0.8	0.2	0.3	0.45125	81.38%
1531	Carpenter Hall	0.7	0.5	0.35	0.3	0.3	0.3	0.8	0.2	0.3	0.42125	75.97%
1543	Corson/ Mudd Hall	0.2	0.5	0.5	0.2	0.3	0.3	0.8	0.2	0.3	0.41375	74.62%

1328	Cradit Farm at Balch Hall	0.7	0.5	0.15	0.3	0.3	0.3	0.8	0.5	0.1	0.379	68.35%
1547	Dairy Bar	0.2	0.5	0.35	0.5	0.3	0.3	0.8	0.2	0.3	0.4025	72.59%
1546	Dairy Bar across street	0.7	0.5	0.35	0.3	0.3	0.3	0.8	0.2	0.6	0.45275	81.65%
1524	Goldwin Smith Hall	0.7	0.5	0.15	0.3	0.3	0.3	0.8	0.2	0.3	0.38125	68.76%
1345	Jessup @ Pleasant Grove	0.7	0.5	0.15	0.3	0.3	0.3	0.8	0.3	0.6	0.419	75.56%
1356	Jessup @ Triphammer	0.1	0.2	0.15	0.2	0.3	0.2	0.8	0.5	0.6	0.31375	56.58%
1542	Kennedy Hall	0.2	0.5	0.35	0.3	0.3	0.3	0.8	0.2	0.3	0.39	70.33%
1342	Northcross @ Jessup	0.2	0.5	0.15	0.3	0.3	0.3	0.8	0.5	0.6	0.40025	72.18%
1326	Risley Hall - Shelter	0.7	0.2		0.2	0.2	0.3	0.8	0.2	0.6	0.31025	55.95%
1525	Rockefeller Hall	0.2	0.5	0.15	0.3	0.3	0.3	0.8	0.2	0.3	0.35	63.12%
1534	Sage Hall	0.2	0.5	0.5	0.5	0.5	0.5	0.8	0.2	0.3	0.473	85.30%
1703	State/MLK @ Quarry	0.2	0.5	0.35	0.3	0.3	0.3	0.8	0.2	0.3	0.39	70.33%
1533	Statler	0.2	0.5	0.5	0.5	0.5	0.5	0.8	0.2	0.3	0.473	85.30%
1507	Stewart @ University	0.2	0.5	0.15	0.5	0.5	0.5	0.8	0.3	0.6	0.44075	79.49%
1325	Thurston at Balch Hall	0.7	0.5	0.35	0.3	0.3	0.3	0.8	0.2	0.3	0.42125	63.35%
1540	Uris Hall across street	0.2	0.5	0.5	0.3	0.5	0.3	0.8	0.3	0.3	0.43875	54.91%
1555	Vet School	0.1	0.5	0.35	0.3	0.3	0.3	0.8	0.2	0.3	0.38375	69.21%

Maximum	0.473
Potential Highest Total score	0.5545

Based on the standards, the team rated each requirement for each shelter as the table shown above. The total score of each shelter was calculated by the sum product of the rates of the requirements for each shelter and the weights of the requirements. The maximum total score of the shelters is 0.473, which are in the stops named Sage Hall and Statler. The potential highest total score was calculated by the highest rates of the requirements and the weights of the requirements, which is 0.5545. Thus, the percentage was calculated by using the total score of each shelter by the potential highest total score. Moreover, the percentage illuminates how well the shelters can meet the requirements.

Stops Without Shelters

The process for evaluating stops without shelters was similar to the process of stops with shetlers, but with some different requirements and goals. Based on these goals, the team first came up with five requirements to determine which stops can build a new shelter. The requirements are shown below:

Goals
Ensure there is enough space to build a new shelter.
Maximize the number of routes.
Ensure there are lights around during the night.
Ensure the stops are on pavement.
Ensure the ground of the stop is even.

Then, in the AHP, the team classified these requirements into two groups: Make It Easy to Build a Shelter and Make the Shelter Useful in the Future. Next, the team assigned a weight for each requirement in each group. The final weight of each requirement is the product of group weight and the requirement weight in the groups.

Make it easy to build a shelter			Make the shelter useful in the future	
0.5			0.5	
Ensure there is enough space to build a new shelter.	Ensure the stops are on pavement.	Ensure the ground of the stop is even.	Ensure there are lights around during the night.	Maximize the number of routes.
0.5	0.3	0.2		
			0.4	0.6
0.25	0.15	0.1	0.2	0.3

The standards for the stops without shelters were created in a similar way to the standards for the stops with shelters. The goal was to make sure that both types of stops with and without shelters were making the requirements that the team had established.

Space	Large	Medium	Small
	0.6	0.3	0.1
Pavement	Small	Medium	
	0.8	0.2	
Even Ground	Even	low Slope	high Slope
	0.6	0.3	0.1
Light	Yes	No	
	0.8	0.2	
Route Numbers	Many	Normal	Few
	0.5	0.35	0.15

Based on the standards, the team also gave a rating for each of the requirements for each stop. Moreover, the team followed the same manner to calculate the total scores for the stops, the potential highest total score and the percentages. The result table are shown below. The stop named Anabel Taylor Hall received the highest total score, which is 0.64. This highest score is equal to the potential highest score, so the percentage is 100%, which means this stop meets all the requirements.

Stop Number	**Stop Name**	**Space**	**Pavement**	**Even Ground**	**Light**	**Current Route**	**Total Score**	**Percentage**
1530	Anabel Taylor Hall	0.6	0.8	0.6	0.8	0.5	0.64	100.00%
1513	Baker Flagpole	0.3	0.8	0.6	0.8	0.35	0.52	81.25%
1512	Baker Flagpole - Slope Side	0.1	0.8	0.6	0.8	0.35	0.47	73.44%
1511	Boldt Hall	0.3	0.8	0.3	0.8	0.15	0.43	67.19%
1553	Boyce Thompson Institute	0.3	0.8	0.3	0.8	0.5	0.535	83.59%
1535	Campus @ Hoy	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1710	College @ Mitchell (Blair Side)	0.1	0.8	0.3	0.8	0.35	0.44	68.75%
1711	College @ Mitchell (Linden Side)	0.1	0.8	0.3	0.8	0.35	0.44	68.75%
1715	Collegetown Crossing	0.6	0.8	0.3	0.8	0.35	0.565	88.28%
1331	Cradit Farm @ Pleasant Grove	0.1	0.8	0.1	0.8	0.15	0.36	56.25%
1119	Gun Hill Apartments	0.1	0.8	0.1	0.8	0.15	0.36	56.25%
1120	Gun Hill Apartments	0.1	0.2	0.1	0.8	0.15	0.27	42.19%
1349	Hasbrouck Apts	0.6	0.8	0.6	0.8	0.35	0.595	92.97%
1329	Helen Newman Hall	0.6	0.8	0.6	0.8	0.15	0.535	83.59%
1316	Highland @ Lakeland	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1317	Highland @ Lakeland	0.1	0.8	0.3	0.8	0.15	0.38	59.38%

1310	Highland @ Thurston	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1315	Highland @ Wyckoff	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1314	Highland @ Wyckoff	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1537	Hoy @ Campus	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1751	Humphreys Service Building	0.3	0.8	0.6	0.8	0.15	0.46	71.88%
1752	Humphreys Service Building	0.1	0.2	0.3	0.8	0.15	0.29	45.31%
1746	Ithaca @ Elmwood	0.3	0.8	0.3	0.8	0.15	0.43	67.19%
1747	Ithaca @ Elmwood	0.3	0.8	0.3	0.8	0.15	0.43	67.19%
1346	Jessup @ Pleasant Grove	0.3	0.8	0.6	0.8	0.35	0.52	81.25%
1355	Jessup @ Triphammer (CC Lot Side)	0.3	0.8	0.1	0.8	0.35	0.47	73.44%
1753	Maple @ Veterans - Maplewood Apts	0.3	0.8	0.3	0.8	0.15	0.43	67.19%
1521	Milstein Hall	0.6	0.8	0.6	0.8	0.15	0.535	83.59%
1520	Milstein Hall Across Street	0.3	0.8	0.6	0.8	0.15	0.46	71.88%
1339	Northcross at RPCC	0.6	0.8	0.6	0.8	0.15	0.535	83.59%
1347	Pleasant Grove @ Jessup (northbound)	0.3	0.2	0.6	0.8	0.35	0.43	67.19%
1348	Pleasant Grove @ Jessup (southbound)	0.3	0.8	0.6	0.8	0.15	0.46	71.88%
1323	Risley Hall - Front	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1343	Robert Purcell Community Center	0.6	0.8	0.6	0.8	0.35	0.595	92.97%

1344	Robert Purcell Community Center (Townhouse Side)	0.6	0.8	0.3	0.8	0.15	0.505	78.91%
1716	Schwartz Performing Arts Center	0.6	0.8	0.3	0.8	0.5	0.61	95.31%
1704	State/MLK @ Quarry	0.1	0.8	0.3	0.8	0.5	0.485	75.78%
1702	State/MLK @ Stewart	0.3	0.8	0.3	0.8	0.5	0.535	83.59%
1721	Stewart @ Seneca	0.1	0.8	0.3	0.8	0.5	0.485	75.78%
1722	Stewart @ Seneca (Luna Side)	0.1	0.8	0.3	0.8	0.5	0.485	75.78%
1506	Stewart @ University	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1725	Stewart @ Williams	0.1	0.8	0.1	0.8	0.5	0.465	72.66%
1726	Stewart @ Williams (Luna Side)	0.3	0.8	0.3	0.8	0.5	0.535	83.59%
1307	Thurston @ Barton	0.1	0.2	0.3	0.8	0.15	0.29	45.31%
1306	Thurston @ Barton	0.1	0.2	0.3	0.8	0.15	0.29	45.31%
1308	Thurston @ Highland	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1311	Thurston @ Highland	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1309	Thurston @ Highland	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1301	Thurston @ Stewart	0.1	0.2	0.1	0.2	0.15	0.15	23.44%
1360	Triphammer @ Country Club Rd	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1361	Triphammer @ Country Club Rd (Field Side)	0.3	0.2	0.3	0.8	0.15	0.34	53.13%
1358	Triphammer @ Dearborn	0.6	0.8	0.3	0.8	0.15	0.505	78.91%

1367	Triphammer @ Iroquois	0.3	0.2	0.3	0.2	0.15	0.22	34.38%
1368	Triphammer @ Iroquois	0.1	0.2	0.3	0.2	0.15	0.17	26.56%
1357	Triphammer @ Jessup	0.6	0.2	0.3	0.8	0.15	0.415	64.84%
1373	Triphammer @ Northway	0.6	0.8	0.6	0.8	0.15	0.535	83.59%
1372	Triphammer @ Northway	0.3	0.2	0.6	0.8	0.15	0.37	57.81%
1363	Triphammer @ Oak Hill (Northbound)	0.1	0.2	0.3	0.8	0.15	0.29	45.31%
1362	Triphammer @ Oak Hill (Southbound)	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1111	University @ Cornell Ave	0.3	0.8	0.3	0.8	0.15	0.43	67.19%
1113	University @ Lake	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1508	University @ Stewart	0.1	0.8	0.3	0.8	0.15	0.38	59.38%
1541	Uris Hall	0.6	0.8	0.3	0.8	0.5	0.61	95.31%
1556	Vet Medical Center	0.3	0.8	0.6	0.8	0.35	0.52	81.25%
1557	Vet Medical Center (parking lot side)	0.1	0.8	0.6	0.8	0.35	0.47	73.44%
1322	Wait @ Thurston	0.1	0.8	0.3	0.8	0.15	0.38	59.38%

Maximum	0.64
Potential Highest Total Score	0.64

Context Diagram

In order to build up a database for Masterplan, it was essential to determine the stakeholders first. Additionally, figuring out what are the interactions between the Masterplan database and each stakeholder are equally important. Here, the context diagram helps to understand all the relationships within the Masterplan database.

Furthermore, the team was able to learn about the stakeholders from the diagram. The context diagram can be seen below:

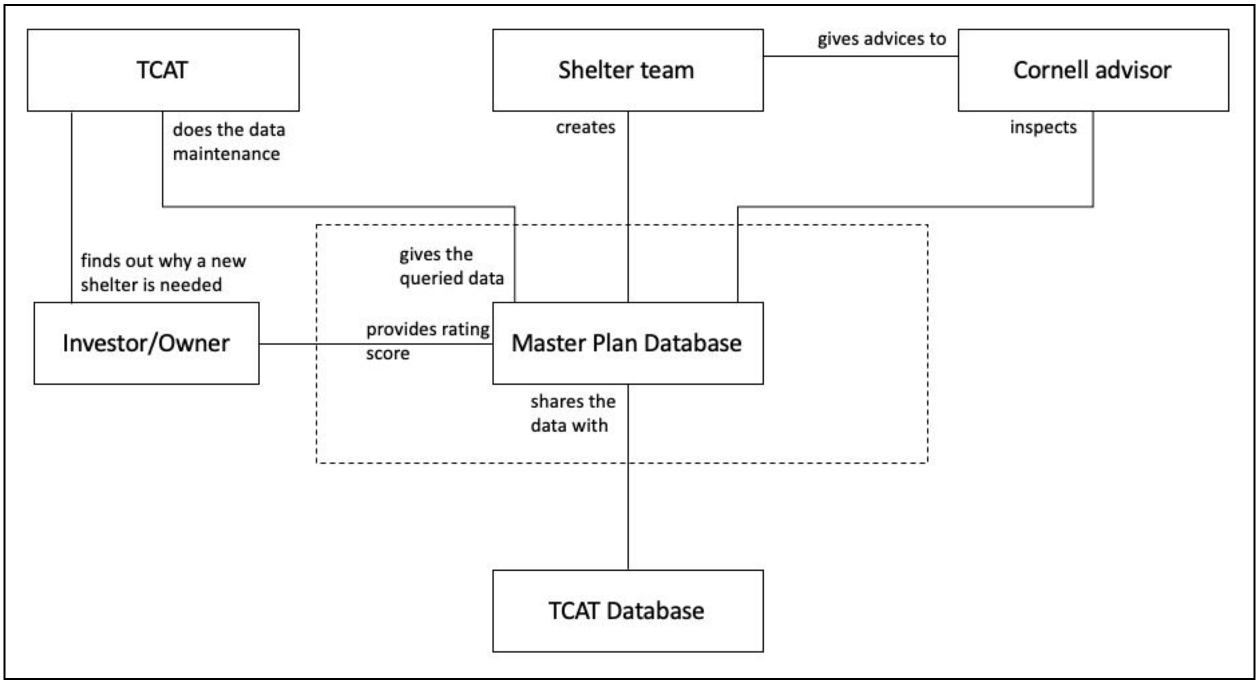


Figure 22: Masterplan Database Context Diagram

In this context diagram, it is crucial for the Masterplan database and the system at large to be well-designed. The system is placed in the dotted box at the center of the diagram. Any other items out of the dotted box are the environment entities which are not included within our system; but all these items will have interactions within our system. Additionally, some of the environment entities may have reactions with each other. In the context diagram, we use the solid line to indicate relationships of interactions between two entities or between entities and the system. The context diagram assists with deepening the understanding of the relationships between the Masterplan database and all the stakeholders. The table below clearly illustrates this:

Stakeholders	**Responsibility to Masterplan Database**	**Benefit from Masterplan Database**	**Other insights about Masterplan Database**

Shelter team	Shelter team should prototype the creation and initial upkeep of the Masterplan corresponding to student availability	N/A	Shelter team should create the database with the help of TCAT, the Cornell advisors and any other relevant parties
TCAT	Give feedback during the initial creation and maintain upkeep of the formal database	Masterplan database can provide the queried data to TCAT.	TCAT could use masterplan database to analyze data and find out where the new shelter should be placed.
Investor/Owner	N/A	Masterplan database has to give a numeric rank of demand of new shelter.	Masterplan should be able to help TCAT attract more passengers taking the bus.
Cornell Advisor	Cornell advisor should provide feedback to shelter team	N/A	N/A
TCAT Database	N/A	N/A	Masterplan database is better able to connect with TCAT's main database, so that information can be shared immediately.

Figure 23: Extrapolated Context Diagram

Database Analysis

Before starting to develop a database for the Masterplan, the team had to understand what functions it should have. To analyze the problem of what the database should achieve, the team decided to implement the system tool of "Use Case". This assists with determining for what scenarios the users of the database would utilize the system (database). Thus, the team employed another systems tool called "Behavioral Diagram" to list out the steps of a supposititious process for each use case. By knowing the details in every use case, the team was able to conclude all requirements which the system should have.

	System: Masterplan Database	
	Use cases	Priority
1	User prioritizes the stops where a new shelter is needed urgently	High
2	User learns about the spatial info	Medium
3	User queries about the cost information	Medium
4	User updates the data in the database	Medium
5	User knows the route numbers of the stops	High
6	User knows the owner information of the stops and shelters	Medium
7	User knows the address of the stops	High
8	User knows which stops have shelters	High
9	User knows basic information of the shelters	Low
10	User looks at the pictures of the shelters	Medium
11	User reads the descriptions of the shelters	High
12	User checks the ridership data of the stops	High
13	User knows the assessments of the features of the shelters	High

Figure 24: Use Cases

The Use Cases Table showed some activities that users can perform with the database. Moreover, it offered the team a clear list about what user operations should be achieved in the database system, and what kinds of services the Masterplan database can provide to users. Based on customer needs, the Use Cases converted the needs to be specific user activities that will be performed in the system. It further determined what required functions need to be completed by the team. It was also a guideline for future progress. Since it is only a list of some independent user activities, the team would like to simulate a sequence of user activities by using the Use Case Diagram, Use Case Behavioral Diagram and other tools to get a better understanding of realistic methods of application for the shelter system.

Use case #1	
User prioritizes the stops replacement	
Initial Conditions	
1. Every stop has all data about its conditions information, without the score of each stop	
2. The current database does not provide the scores for all of the stops, which determines the order of replacing the stops	
Operator (User)	**System (The masterplan database)**
User opens the database	
	The Masterplan Database will be able to load and save quickly
	The Masterplan Database will show all the latest data
	The Masterplan Database will have a clear instruction operation
User utilizes the database to get a score for every stop	
	The Masterplan Database will be able to calculate a score for stop's condition automatically
User wants to know which stops need the replacements	
	The Masterplan Database will rank the priority of shelter replacement
Ending Conditions	
1. Database includes the score of each stop	

2. The stops are ranked by the replacement priority according to the score	

Use case #2		
User updates the data in the database		
Initial Conditions		
1. The data in the database is not the latest version		
2. The data is well organized		
3. The database is secured		
Operator (User)	**System (The masterplan database)**	**Administrator**
User tries to change the data directly		
	The Masterplan Database will protect the data from unauthorized change	
User enters the special identification to pass the protection		
	The Masterplan Database will recognize the users' identification	
User tries to change the data again		
	The Masterplan Database will have an easy method to update the data	
User exits the modification mode		

	The Masterplan Database will be able to load and save quickly	
	The Masterplan Database will return to the security mode after each time update	
	The Masterplan Database will notify the administrator when the data is changed	
		Administrator takes a look at the new data
		Administrator corrects any mistakes in the new data to keep it well organized
Ending Conditions		
1. Database has the latest data		
2. The data is still well organized		
3. The database is still secured		

The behavioral diagram here is starting from the initial conditions and finishing at the ending conditions. It shows how the user will implement the system in the use case and how the system will respond to the user's implementation. According to the behavioral diagram, it is very easy to find out all the requirements of the system as shown under the system's responding.

Index	Originating Requirements	Abstract function name
OR.1	The Masterplan Database will show all the latest data	Latest data
OR.2	The Masterplan Database will be able to give a query result	Query answer

OR.3	The Masterplan Database will rank the priority of shelter replacement	Shelter replacement
OR.4	The Masterplan Database will protect the data from unauthorized change	Data protection
OR.5	The Masterplan Database will have an easy method to update the data	Data update
OR.6	The Masterplan Database will have a good data structure for future development	Data structure
OR.7	The Masterplan Database will have a clear operation instruction	Operation instruction
OR.8	The Masterplan Database will be able to calculate a score for stop's condition automatically	Score calculation
OR.9	The Masterplan Database will recognize the users' identification	User ID recognition
OR.10	The Masterplan Database will be able to do quick saving and loading	Quick saving and loading
OR.11	The Masterplan Database will notify the administrator when the data is changed	Notification to administrator
OR.12	The Masterplan Database will return to the security mode after each time update	Continuous protection

Figure 25: Originating requirements

Before the Masterplan team completes the system, the team used the Originating Requirements Table to list all the potential customer requirement that should be realized by the system. There are some user behavior requirements and parameter requirements in the Originating Requirements Table. The user behavior requirements defined the potential services that the system could provide to users. In addition, the parameter requirements are the parameters that should be defined for the system, which are also some limitations for the project.

The Originating Requirements Table helped the team better understand what functions the system should include and what limitations could be considered in the design process. This system tool provided a relative more specific range of the project.

Spreadsheet & Database Prototype

Our new spreadsheet consisted of multiple different variables, including several pulled directly from the previous prototype. By combining the work from last semester, as well as conducting preliminary empathy fieldwork, we managed to document 90 stops and shelters using the following metrics:

Type	Whether we are observing a regular stop, or a stop with a shelter
Stop ID	The stop ID in the TCAT system
Stop Name	The stop name from TCAT routing map
Longitude	The longitude of the corresponding bus stop
Latitude	The latitude of the corresponding bus stop.
Street Location	The closest street location of the bus stop within the municipality
Jurisdiction	The municipality where the stop or shelter was located
Size	The relative size of the shelter, or the standing area for a stop. Later in the semester we started taking measurements of these locations
Physical Construction Materials	The materials used in the construction of the shelter, or the materials present in the area of the stop, such as pavement or grass
Special Features	A select number of the newer shelters have special features, such as display screens or interior lighting
Current Routes	All routes which pass through this bus stop.
Size (tool)	A number used by the systems students to rate the size of the stop or shelter
Construction Materials (tool)	A number used by the system students to rate how good the construction materials are
Current Routes (tool)	A number used by the system students to rate how many the route numbers in this stops are

Aesthetic Condition (tool)	A number used by the system students to rate how good the aesthetic condition is
Structural Integrity (tool)	A number used by the system students to rate how good the structural integrity is
Functionality /Ease of Use (tool)	A number used by the system students to rate how good the functionality is
Light (tool)	A number used by the system students to rate whether there is light around the shelter or not
Ability to Keep Warm Inside (tool)	A number used by the system students to rate the ability of shelter to keep warm inside
Seats (tool)	A number used by the system students to rate whether there are seats in the shelter or not
Total Score (of tools)	A number used by the system students to rate how much the shelter can meet the requirements
Score Percentage	How the score of a shelter or stop compares to the rest of the shelters or stops
Ridership Data	The ridership data by stop for the 2017-2018 year from TCAT
Relative Aesthetic Condition	A qualitative impression of the appearance of the shelter, not to be confused with numerical rating of the aesthetic condition. While the numerical rating is important, it means very little if a potential user is unlikely to see the shelter as useful in the first place
Relative Structural Integrity	A qualitative impression of the structural integrity of the shelter, not to be confused with numerical rating of the structural integrity . While the numerical rating is important, it means very little if a potential user sees the shelter as unstable or dangerous
Functionality /Ease of Use	An overall qualitative impression of the shelter or stop and a judgement on how well the shelter or stop serves its purpose
Relative Capacity	The amount of use the shelter or stop received given the size of the shelter or stop

Link to Google Drive Folder with Pictures and Full Notes	A link to a folder in the cloud with additional photos and a brief description of observations

Figure 26: Shelter spreadsheet Prototype

Note that the spreadsheet for stops was largely the same. However, some new variables were added:

Space (tool)	A number used by the system students to rate how much space around the stop can be used to build a new shelter
Pavement (tool)	A number used by the system students to rate whether there is a pavement near the stop or not
Even Ground (tool)	A number used by the system students to rate how even the ground is
Light (tool)	A number used by the system students to rate whether there is light around the shelter or not
Current Route (tool)	A number used by the system students to rate how many the route numbers in this stops are

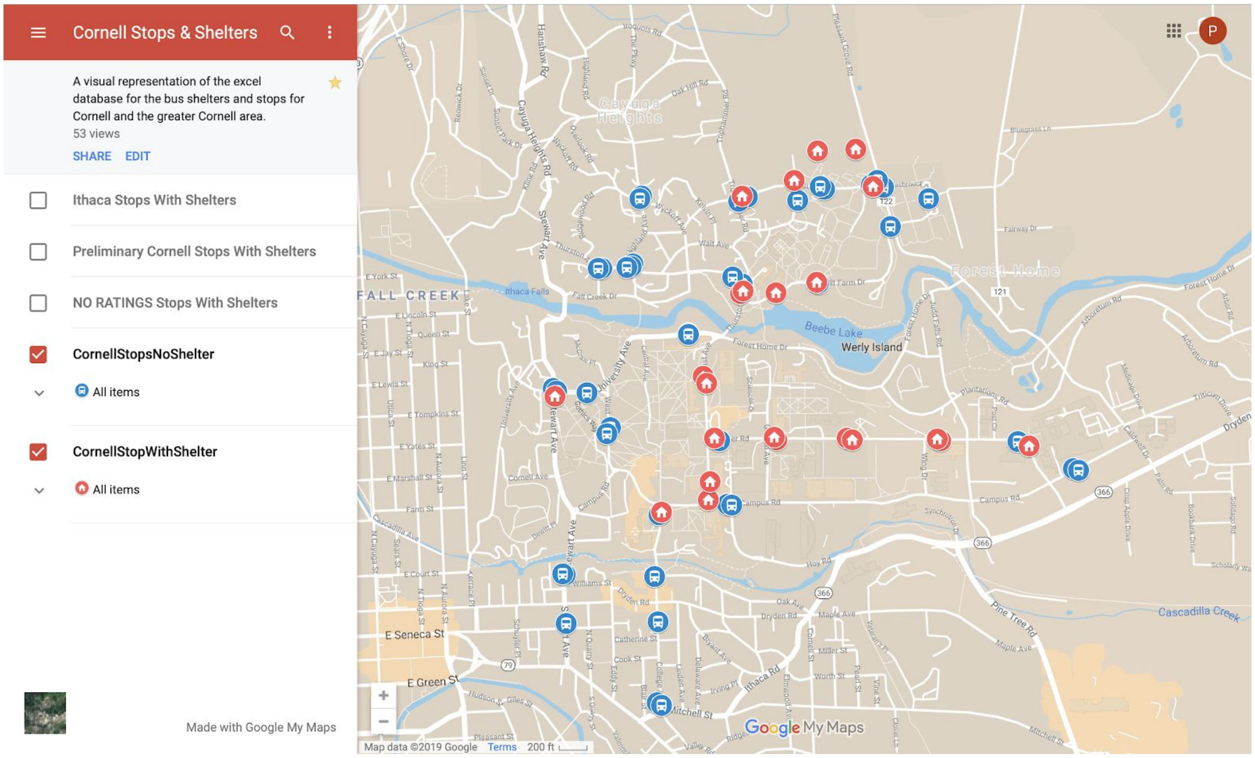
Additionally, the stop spreadsheet did not include the **Special Features**, **Relative Aesthetic Condition,** and **Relative Structural Integrity** variables, as that only applied to shelters.

Overall, the current iteration of the spreadsheet is the one that the team will likely continue to use next semester. Unfortunately, there were several variables, such as the owner of the land of the shelter or stop, and the construction date of the shelters, and the responsibilities for maintaining a stop or shelter, that we were not able to find. While the team asked Cornell Transportation and TCAT for this information, neither of them had the information or knew where to find it. However, TCAT did express a great deal of interest in finding this out.

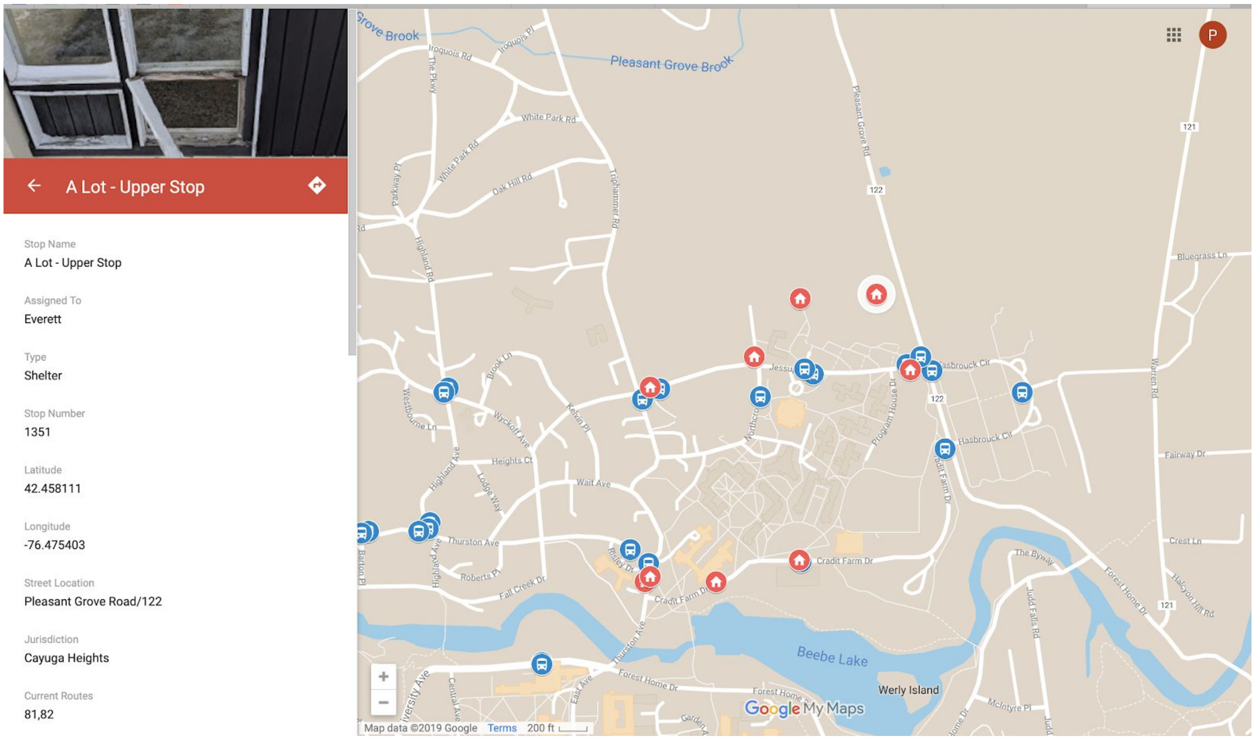
Currently, TCAT maintains some aspects of the shelter's on campus while Cornell maintains others. For example, TCAT may pressure wash and clean Cornell shelters in the Spring, but during the winter, Cornell removes the snow in and around the shelters. We hope to be able to gain some clarity on the situation next semester.

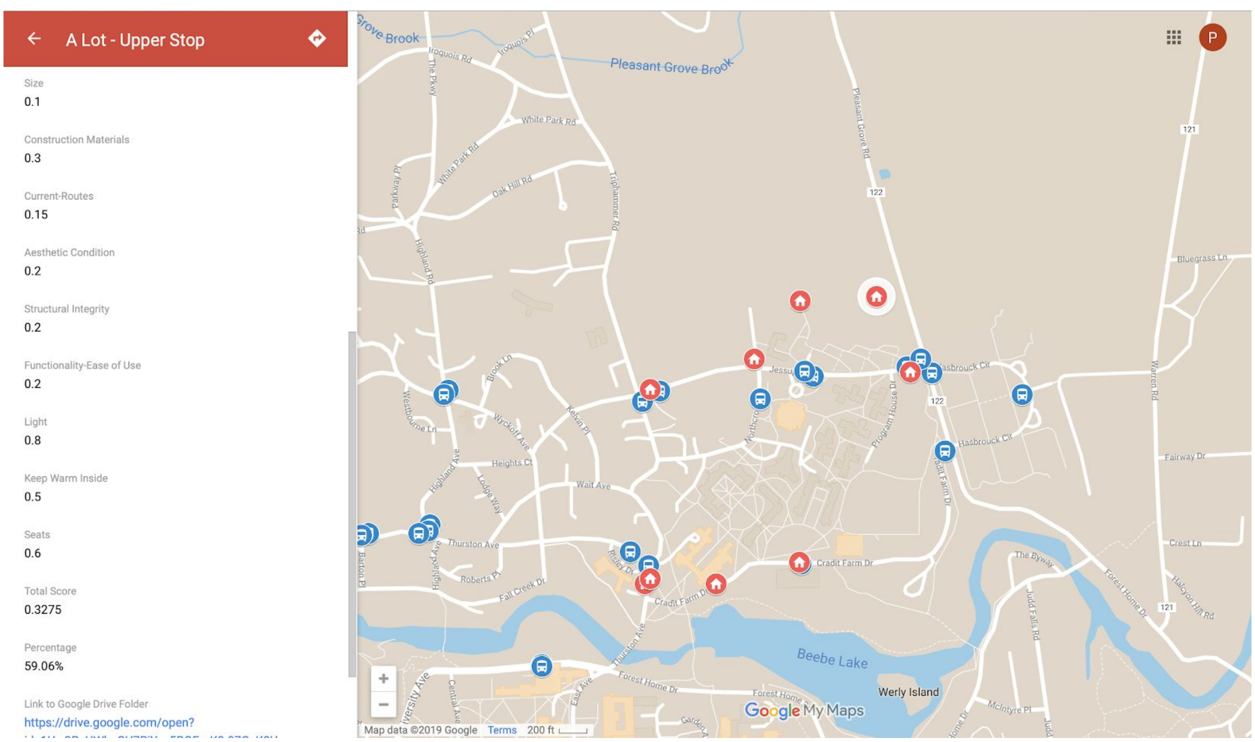
Visual Component

In addition to the quantitative spreadsheet, we were able to transfer this information into a visual component. We chose to use Google Maps “MyMaps” which allowed for a relatively easy transition of information. Below is a screenshot of the map



The red/orange icons with a home represent shelters, while the blue icons with a bus represent regular stops. By selecting a shelter or stop, a user can see much of the same information from the spreadsheet:





For example, this is one of the shelters at A-Lot. The shelter is a blight on the campus and is beyond repair. The user is able to see a picture of the shelter, the name of the shelter, the person that made the observations, the location, stop number, latitude, longitude, street location, current routes, the system rating tools, the total score and percentage, and more pictures and observations in a shared folder in the cloud.

Stakeholder Meetings

As mentioned earlier, we were able to present the spreadsheet and map to TCAT. The meeting consisted of Matt Yarrow, Assistant General Manager, Service Development and Planning, Raymond Lalley, Purchasing Manager, and Megan Pulver, Projects Manager, as well as our faculty advisor, Siri Simoncini, the systems students (including a distance learning student), and other Masterplan team members.

We presented the map and the spreadsheet that the team created and TCAT was very happy with the results. They expressed an interest in continuing the Masterplan project and informed us that they had additional variables they would like us to consider. We hope to implement those new variables next semester.

Additionally, we were able to meet with representatives from Cornell Planning and Landscape Architecture to determine a possible future site for the student designed bus shelter. We discussed several sites, notably the shelters at A-Lot or Risley Hall, and hope to continue working with them alongside the Shelter Design Team next semester.

Future Work

Next semester, the team hopes to continue our work and complete the stops and shelters within the City of Ithaca. We are also anxiously awaiting to hear back from TCAT on what variables they wish for us to add in our evaluations and will revisit our past observations to include these new criteria.

After the stops and shelters in the City of Ithaca are completed, we hope to continue our evaluations throughout the county. This likely will not be completed next semester, but there is a chance that we may be able to start working on this near the end of the next semester.