Sustainable Bus Stop: Design & Pre-Construction

Nadov O Rader, CM
California Polytechnic State University
San Luis Obispo, CA

The objective of this project is to design and prepare to build a sustainable bus stop for the City of San Luis Obispo (SLO). Compiled are pre-construction plans and documents for delivery of a sustainable bus stop. All pre-construction services include: project budget/estimates, construction plans and specifications including architectural and electrical plans, timeline/schedule, and materials lists. With a strong focus on sustainability, the design incorporates the use of photovoltaic panels as a form of renewable energy to power features of the sheltered bus stop. This includes a light fixture and a pump to use collected rainwater to nourish native vegetation in a planter box. The budget was to be under $10,000 and includes all labor and materials for the construction phase of the project. The schedule for the construction phase is within a two week timeline during the end of March, 2021. The risk analysis includes a Risk Register which uses the Severity Table and Risk Breakdown Structure (RBS) together to evaluate the risk of specific events of the project. The RBS consists of the following four categories: Environmental, Resources, Management, and Construction. Plan documents meet all local building codes per the requirements of the City of SLO.

Key Words: Sustainable, Design, Pre-Con, Bus Stop, Bus Shelter

Introduction

The construction industry has recently been acknowledged for its strong focus on green building and sustainability. Whether it be a marketing strategy or has honest intent behind it, industry leaders have strived to focus on building more efficiently through use of materials, building processes, managerial and technological advancements, as well as finding ways to conserve energy. These companies, however, work on multi-million dollar projects which have many different ways to attack sustainability and use energy more efficiently.

The focus of this project was to zoom in and focus on building sustainably on a smaller scale. The City of SLO uses a very standard and simple design when it comes to their sheltered bus stops. Finding ways to incorporate sustainable sources of energy is important. This prototype could be used

for more than just one location, it's expected to be implemented on future bus stops throughout the City of SLO.

Design

The public transit in San Luis Obispo is all above ground and exposed to the surrounding environment. The idea behind the concept of this project's design was to incorporate the exposed location of where the bus stop is to be built. Nestled in the valley between two iconic mountain peaks, the bus stop sits on the corner of W. Foothill Blvd. and Narrow Ct. With Bishop Peak on one side and Cerro San Luis Obispo (more commonly known as Madonna Peak) on the other, the architecture of the roof, in section view, resembles the two peaks converging in the valley where the bus stop resides.

Renewable Energy and Photovoltaic Modules

The sustainable features all rely on renewable energy as a source of power. Both roofs feature photovoltaic panels which are exposed directly to the sun throughout the day. Although one panel will receive more sunset due to the southern facing tilt, the other panel will get more sun exposure in the afternoons. Each panel is to be 450W cumulating 900W which, on a 12V system, is 75amps.

Charge Controller and DC Power

Step one was to determine the amps produced from the solar panels. This was important to know first because it determined which charge controller to use. This was determined using the Maximum PV Input Power which is calculated with the algorithm Maximum Power Point Tracking (MPPT) that is included on the charge controller specifications. The photovoltaic panels absorb sunlight and the solar cells convert that energy into DC power. Keeping all electrical systems on DC power eliminated the need for an inverter at this small scale project. The charge controller limits the battery from overcharging.

Battery and Lighting

In coordination with the DC system, the battery was determined to be a 12V 170AH DC Lithium-Iron Phosphate Battery. This was recommended based on the charge controller specifications and fell into coordination with the DC system. The battery powers two features of the bus stop; a pump to water the planter box and a light fixture to be mounted on the top rail of the structure facing downwards to avoid light pollution. The light is to be a 12V LED DV motion sensor light fixture. Light-Emitting Diode (LED) is one of the top energy efficient lighting technologies today.

Native Vegetation

The planter box in the shelter consisted of native plants that are used to the conditions of the area. A local landscaping company, Wild Bloom, suggests the following three plants: California Fuchsia (Zauschneria californica), Deer Grass (Muhlenbergia rigens), and California Buckwheat (Eriogonum fasciculatum). These plants are not only native to the area but require very limited maintenance as they are extremely drought tolerant.

Irrigation and Pump

The pump to be installed at the shelter will be a 12V DC 1.2GPM pump. An irrigation timer is then to be installed in between the pump and the spout to the plants. This will allow the flow to be controlled, limited, and set on a timer for different days of the week for as little as 1 minute. To prepare for the dry season in San Luis Obispo the rain water collection system will fill up a 12 gallon tank, with an overflow outlet included. For the six month period (May-October) that is expected to be hot and dry, the irrigation timer will be set to run once every other week for one minute, releasing 1.2 gallons for the plants. This twice a month watering schedule should allow the 12 gallon tank to be sufficient for the sixth month dry season.

Project Deliverables

The project consisted of managing the pre-construction phase of this project, including the delivery of architectural and electrical plans and specifications, drawing renderings, a materials list, a budget, a schedule, and a risk analysis. The architectural plans consisted of a floor plan, roof plan, and a section cut. The specifications come from the materials list and are called out on the plans. The materials list includes a written explanation for chosen materials and provides material specifics for procurement. The budget was to be under $10,000 and accounts for all labor and materials for the construction phase of the project. It includes the budgeted amount for each line item as well as the estimated actual cost. It shows the difference and indicates which items have a buffer and which do not. The schedule includes the pre-construction work but focuses on the construction phase of the project which is to be completed in two weeks, excluding weekends. The schedule is divided into the following categories: site preparation, foundation, structure, electrical, and closeout. The risk analysis utilizes a Risk Breakdown Structure (RBS) which consists of risk factors in the following four categories: Environmental, Resources, Management, and Construction. The Risk Register then assesses these risks using the Severity Table and proposes mitigating action and contingent action that the owner of the risk should assume.

Inspiration and Development

The current focus in the construction industry is on managerial and technological advancements. This encompasses, but doesn't emphasize enough, the importance of green building. Although industry leaders are implementing processes and methods to reduce the impact building has on the environment, the general feel around the industry is that it comes from a place of pleasing the market. Builders know what consumers want, and tailor their methods accordingly. The issue with this is a lack of sincerity and care for the clients' needs. The intent behind the effort is superficial. Having people in the industry who actually care about reducing the impacts on the environment, who have sustainability on the forefront of their minds, and have a moral imperative to help out in some way is important.

The industry needs to shift from within. The culture needs to change to accept and support the protection and conservation of the environment. This project was the first footstep to continue this mindset throughout future companies and jobs. Expressing and focusing on this topic more and more

will help be a puzzle piece to the bigger picture. Change starts from individuals which leads to the greater good. The current bus stop locations in San Luis Obispo do not all include shelters from rain and sun. The City of SLO does not require a shelter where the expected average number of boarders is less than 8 riders per day. The growing population and student body may provide cause to re-estimate these numbers. I think the community would feel cared about and would appreciate bus stop shelters, especially at the W. Foothill location where the temperatures can be quite high in the hot months and is very exposed to rain in the wet months. Overall, the design of the bus stop is off the beaten path and strays away from the traditional and right-angled bus stop designs that are currently set in SLO. The curved roof with the solar panels and plants will liven up the shelter and provide a more welcoming setting.

The draw to a hands-on project also allowed for an opportunity to gain experience in collaborating and managing multiple parties through the design phase of the project. While getting information from the City, "the owner," and satisfying those needs by relaying that information to the architect who drew the plans. "the designer." The input from professors helped in the production of the electrical plans which acted as a mock electrical subcontractor collaborating with the design team. This was not a one meeting conversation, it required receiving new input throughout the design phase and editing and re-editing the plans accordingly. The collaboration of the project was a part of the draw to this type of hands on, project-based job.

Reflection

The design phase of the project was initiated well before the start of Winter Quarter 2021. The first step was reaching out to the City of SLO and pitching the idea. After an initial email and first contact with Project Manager Manny Guzman, the relationship with the City was smooth and very helpful. They provided bus stop standard specifications. They also provided example plans for a typical bus stop in SLO. After receiving dimension requirements and material requirements, the next step was to brainstorm different design ideas. After researching and analyzing four different design options, we landed on the one that would incorporate all the features we wished to include. The design was finalized after the Materials List was complete. While providing Tom Stuart, Architect Major at Cal Poly, with the requirements from the city and the finalized design idea, the plans started to come to life.

The next step after getting the design phase off the ground was to focus on the deliverables of the project. This included: the schedule, which was to be kept to just two weeks; the budget, which was to be under $10,000; and the risk analysis, which was to include environmental impacts, resource issues, management risks, and construction hazards. The entire process was documented on a log sheet which indicated meetings and benchmarks and general notes. This was more of an organization tool. All meetings took place over *Zoom* and couldn't have gone smoother. Every meeting was time efficient, concise, and productive. The order of operations was mainly on schedule while a few design details went longer than expected. All contacts were very up to date with their tasks and responsibilities and were notified before important benchmark dates were approaching. Emailing, text messaging, and calling were all forms of communication. File sharing was done via email as no document was too large for this delivery method. The project wrapped up with available float remaining in the schedule and deliverables were ready well in time.

The Cons

The project went very smoothly and no major hiccups or delays occurred. With proper preparation to include “float” in the schedule, everything was managed with ease. The first small issue arose with accessibility to design and scheduling software. With the current crises of the pandemic, reaching out to those who had the necessary software on their personal computers were essential. Having a past employer as a good connection allowed for the production of the schedule. The connection with an architect major allowed for the drawings of the plans. The software issue was resolved before Winter Quarter 2021. The project was already underway through preparation in CM 460. The previous term was during the pandemic as well so it was known software would not be as accessible during the production of this project. The next challenge was with the electrical plans. With limited experience and knowledge with electrical plans, this was bound to be a challenge. Connecting with a past employer, a commercial solar company, was a huge help along with the connection of a CM Professor. This part of the project was more involved than expected due to the multiple meetings and gaining of new knowledge throughout the project. The design of the project was supposed to be done early in the pre-construction phase of the project, however, this was prolonged throughout the entirety of the project due to constant additions and omissions of the plans. This was resolved with a dedicated and motivated design team willing to keep editing the plans until near the end of the project. The City was extremely quick to respond during the beginning stages of the project, yet response time increased as the project went on. This was expected and questions asked allowed for plenty of response time. Due to covid, communication became scares and there for I had to assume that no permits would be required for this project as the City of SLO would be performing the work themselves. The only goal not met was due to the budget which ran a little over $10,000. With labor and materials, final costs estimated to be $10,761. This is still a good price and definitely in the ballpark for what a sheltered bus stop would cost. Although it was over the budget, it was still reasonably and fairly estimated. The project as a whole had no major issues. No re-work had to be done, nothing arose that drastically hurt the schedule, and there was enough time budgeted to complete the project with quality.

The Pros

The goals of the project were completed by designing a sustainable bus shelter that offered a more complex and inviting design than what currently exists in the City of SLO. Thanks to the connection with REC Solar, if this design were to be built as a prototype, the solar panels would be donated and is therefore reflected as only a labor cost on the budget. By utilizing photovoltaic modules to power all energy needs made the structure completely self-sufficient. The connections and communication were better than expected. Everyone was motivated and happy to help. The mood was always positive, even when the design was behind schedule. The experience was well worth it and successful through good communication, preparation, and by following through. Having software available from other sources to complete the schedule and plans were an appreciated perk. All meetings were handled with focus and determination. The process was never too dull and also never too overwhelming. The workload was manageable and completing benchmarks was rewarding. The City of SLO would greatly benefit from an updated design for their future bus stop renovations. I expect the community of SLO will appreciate the updated design and effort towards sustainability. The design concept can be used for multiple project locations and possibly be implemented in other sunny cities and counties across the country. Parties involved gained experience in communication, collaboration, design, sustainability, management, scheduling, estimating, analysis of risk, and general networking skills.

Further Development

The City of SLO provided dimensions and specifications for the bus stop shelter, general notes for the title page and Project Manager Manny Guzman showed enthusiasm regarding the project idea. Future development of this project would be making a prototype and pitching the City of SLO to implement this design into the W. Foothill bus stop location. After the first shelter is installed, the next steps would be scouting future locations and perhaps tweak the design to accommodate for each new landscape. Another note on the design of the electrical plans is that there is currently more than enough power supplied than needed for the existing features on the shelter. This allows for future development of additional features to be added. This could include USB charging ports and an electronic bus route sign. A whole garden bed could also be added to bus stops with available space around them. This would require more frequent irrigation and therefore a bigger pump could be accommodated as there is plenty of power supply. Both roofs are equipped with solar modules, allowing for creativity in the development and advancement of features to be added to future designs.

Documentation and Photos

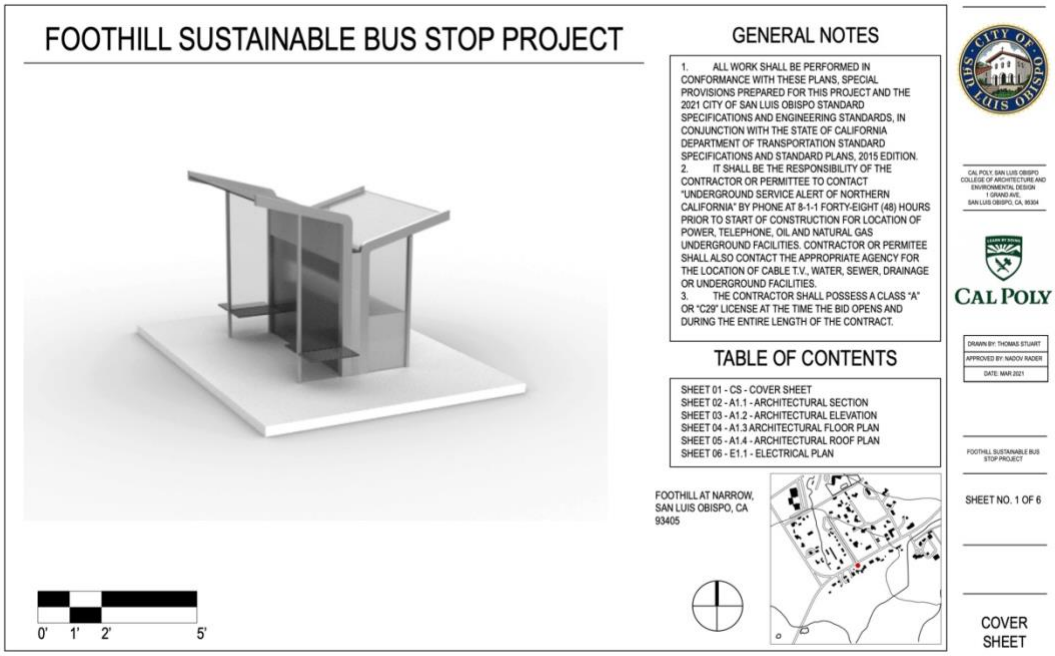


Fig. 1. Cover Sheet of Plans

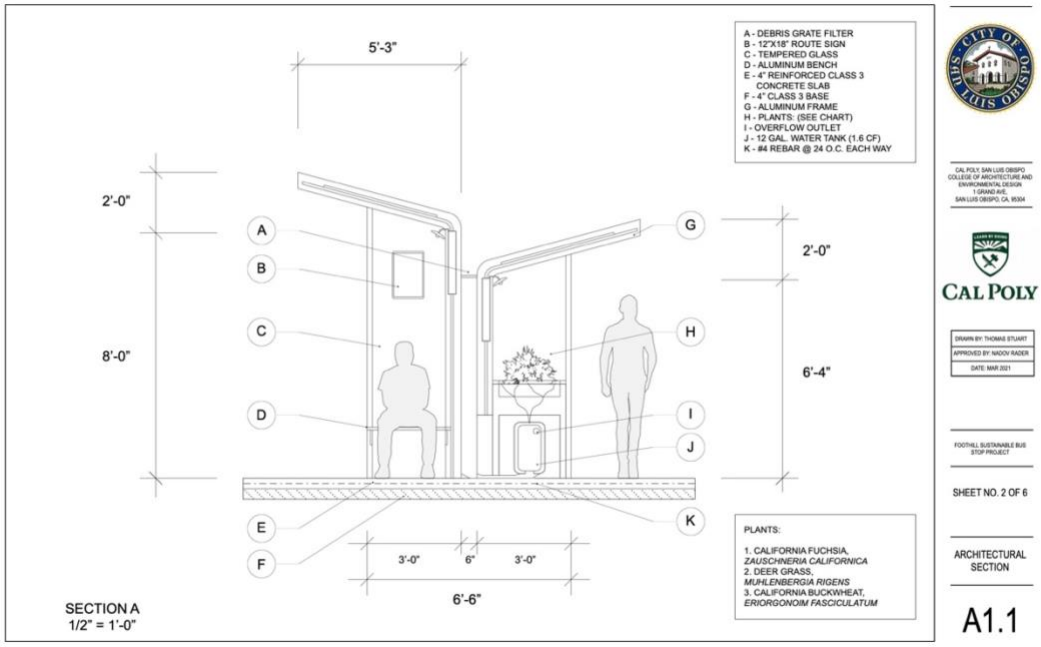


Fig. 2. Section of Architectural Plans

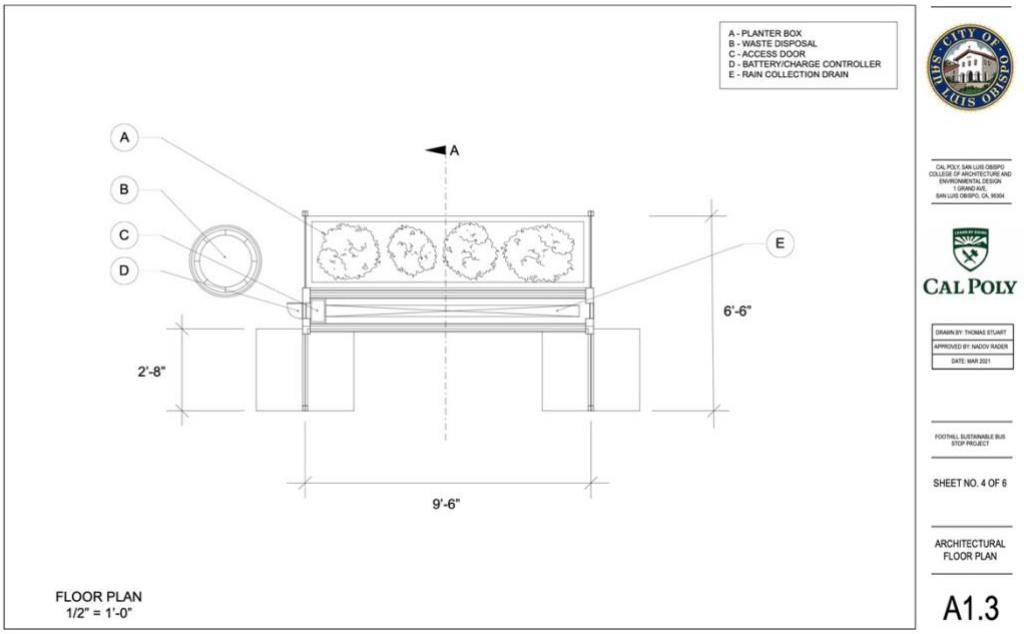


Fig. 3. Floor Plan

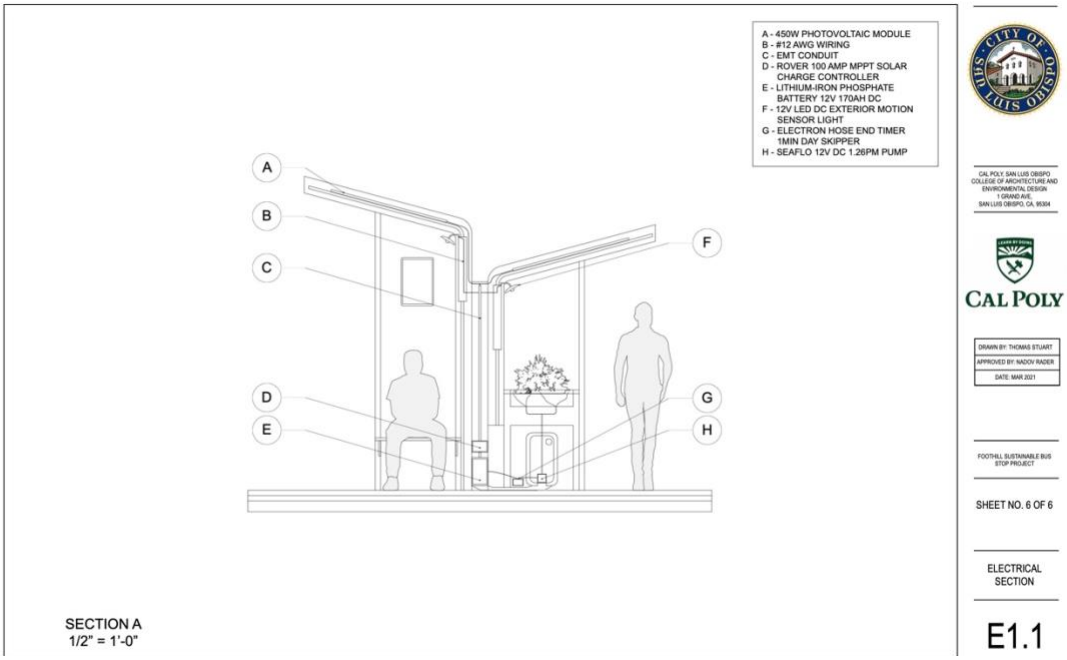


Fig. 4. Electrical Section

		EXPENSES					
START DATE	TASK	LABOR HRS	RATE	UNITS	$ PER UNIT	FIXED COST	ESTIMATED COST
	SITE PREP						
	Boundary Survey and Stakeout	1.00	$ 30.52			$ 200.00	$ 230.52
	Demolition	4.00		180.00	$ 5.00		$ 900.00
	Excavation	4.00		3.33	$ 50.00		$ 166.67
	FOUNDATION						
	Rebar (cut, tie, and place)	2.00	$ 90.00	12.00	$ 40.00		$ 660.00
	Concrete (mix, pour, and finish)	6.00	$ 45.00	400.00	$ 2.78		$ 1,382.00
	Hardward mounted in concrete	0.50				$ 100.00	$ 100.00
	Base Rock	1.00	$ 45.00	2.22	$ 38.00		$ 129.36
	STRUCTURE						
	Install framework	4.00	$ 50.00			$ 1,000.00	$ 1,200.00
	Install glass	1.00	$ 50.00	200.00	$ 5.00		$ 1,050.00
	Install benches	1.50	$ 50.00			$ 1,050.00	$ 1,125.00
	Install trash can	0.50	$ 50.00			$ 350.00	$ 375.00
	Install planter box	0.50	$ 25.00			$ 700.00	$ 712.50
	Install pump	0.50	$ 25.00			$ 30.00	$ 42.50
	ELECTRICAL						
	Install wiring/conduit	1.00	$ 50.00	30.00	$ 6.00		$ 230.00
	Install panels	1.00	$ 50.00				$ 50.00
	Install light fixture	0.50	$ 50.00			$ 120.00	$ 145.00
	Install charge controller	0.50	$ 50.00			$ 700.00	$ 725.00
	Install battery	0.50	$ 50.00			$ 1,275.00	$ 1,300.00
	Install Irrigation timer	0.50	$ 50.00			$ 62.00	$ 87.00
	Connections	1.00	$ 50.00				$ 50.00
	Test electrical	1.00	$ 50.00				$ 50.00
	CLOSEOUT						
	Clean up	0.75	$ 50.00				$ 37.50
	Install bus schedule	0.25	$ 50.00				$ 12.50

Fig. 5. Budget

1 Environmental		2 Resources		3 Management		4 Construction	
1.1	Extreme Heat	2.1	Cash Flow	3.1	Schedule Delays	4.1	Safety Hazards
1.2	Local Ecosystem	2.2	Lack of Funding	3.2	Communication	4.2	Re-work
1.3	Soil Type	2.3	Resource availability	3.3	RFI's	4.3	Unknown Site Condtions
1.4	Natural Disaster	2.4	Labor / Personnel	3.4	Change Orders	4.4	Public

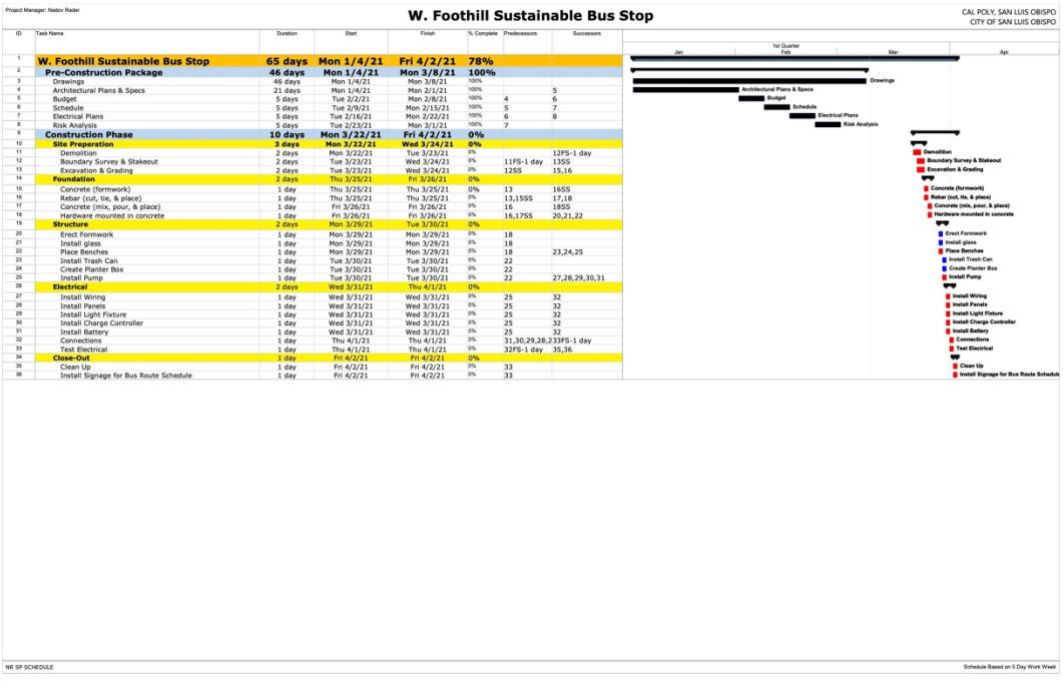
Fig. 6. Risk Breakdown Structure (RBS)

ID	Date raised	Risk descripti	Likelihood	Impact	Severity	Owner	Mitigating actic	Contingent actic	Progress on a	Status
[1.1]	[2/25/2021]	There's a risk the extreme heat in the summer will slow down productivity and delay the schedule	High	Low	Medium	Superintenden & Foreman	Provide a shade tent on site for workers to rest and protect from the hot sun	Accept a slower schedule, do not push workers through extreme heat	No progress reported to date. Reported 2/25/21	Open
[1.2]	[2/25/2021]	Not properly removing all demolition debris can result in negative environment al impacts	Low	High	Medium	Demolition Subcontractor	Ensuring a thurough removal of all demo'd material, not proceeding to build until existing site is clean	Because of the environmental impact, rework would need to be done.	No progress reported to date. Reported 2/25/22	Open
[1.3]	[2/25/2021]	There is a risk that the soil is either harder or looser than expected resulting in structural issues	Low	Medium	Low	Superintenden & Excavation Subcontractor	Conduct a soils report	Find out early, test the soil after excavation and demolition	No progress reported to date. Reported 2/25/23	Open
[1.4]	[2/25/2021]	California has a risk of experiencing a potential earthquake	Low	Medium	Low	PM	Nothing can be done reduce the likelihood of an earthquake occurring	Have all materials on ground level and secured and in place when erect and installed, hard hats are necessary	No progress reported to date. Reported 2/25/24	Open

Fig. 7. Risk Register

		Likelihood		
		1	2	3
Impact	1	Low	Low	Medium
	2	Low	Medium	High
	3	Medium	High	High

Fig. 8. Severity Table



ID	Task Name	Duration	Start	Finish	% Complete	Predecessors	Successors
1	**W. Foothill Sustainable Bus Stop**	**65 days**	**Mon 1/4/21**	**Fri 4/2/21**	**78%**		
2	**Pre-Construction Package**	**46 days**	**Mon 1/4/21**	**Mon 3/8/21**	**100%**		
3	Drawings	46 days	Mon 1/4/21	Mon 3/8/21	100%		
4	Architectural Plans & Specs	21 days	Mon 1/4/21	Mon 2/1/21	100%		5
5	Budget	5 days	Tue 2/2/21	Mon 2/8/21	100%	4	6
6	Schedule	5 days	Tue 2/9/21	Mon 2/15/21	100%	5	7
7	Electrical Plans	5 days	Tue 2/16/21	Mon 2/22/21	100%	6	8
8	Risk Analysis	5 days	Tue 2/23/21	Mon 3/1/21	100%	7	
9	**Construction Phase**	**10 days**	**Mon 3/22/21**	**Fri 4/2/21**	**0%**		
10	**Site Preperation**	**3 days**	**Mon 3/22/21**	**Wed 3/24/21**	**0%**		
11	Demolition	2 days	Mon 3/22/21	Tue 3/23/21	0%		12FS-1 day
12	Boundary Survey & Stakeout	2 days	Tue 3/23/21	Wed 3/24/21	0%	11FS-1 day	13SS
13	Excavation & Grading	2 days	Tue 3/23/21	Wed 3/24/21	0%	12SS	15,16
14	**Foundation**	2 days	Thu 3/25/21	Fri 3/26/21	0%		
15	Concrete (formwork)	1 day	Thu 3/25/21	Thu 3/25/21	0%	13	16SS
16	Rebar (cut, tie, & place)	1 day	Thu 3/25/21	Thu 3/25/21	0%	13,15SS	17,18
17	Concrete (mix, pour, & place)	1 day	Fri 3/26/21	Fri 3/26/21	0%	16	18SS
18	Hardware mounted in concrete	1 day	Fri 3/26/21	Fri 3/26/21	0%	16,17SS	20,21,22
19	**Structure**	2 days	Mon 3/29/21	Tue 3/30/21	0%		
20	Erect Formwork	1 day	Mon 3/29/21	Mon 3/29/21	0%	18	
21	Install glass	1 day	Mon 3/29/21	Mon 3/29/21	0%	18	
22	Place Benches	1 day	Mon 3/29/21	Mon 3/29/21	0%	18	23,24,25
23	Install Trash Can	1 day	Tue 3/30/21	Tue 3/30/21	0%	22	
24	Create Planter Box	1 day	Tue 3/30/21	Tue 3/30/21	0%	22	
25	Install Pump	1 day	Tue 3/30/21	Tue 3/30/21	0%	22	27,28,29,30,31
26	**Electrical**	2 days	Wed 3/31/21	Thu 4/1/21	0%		
27	Install Wiring	1 day	Wed 3/31/21	Wed 3/31/21	0%	25	32
28	Install Panels	1 day	Wed 3/31/21	Wed 3/31/21	0%	25	32
29	Install Light Fixture	1 day	Wed 3/31/21	Wed 3/31/21	0%	25	32
30	Install Charge Controller	1 day	Wed 3/31/21	Wed 3/31/21	0%	25	32
31	Install Battery	1 day	Wed 3/31/21	Wed 3/31/21	0%	25	32
32	Connections	1 day	Thu 4/1/21	Thu 4/1/21	0%	31,30,29,28,23	3FS-1 day
33	Test Electrical	1 day	Thu 4/1/21	Thu 4/1/21	0%	32FS-1 day	35,36
34	**Close-Out**	1 day	Fri 4/2/21	Fri 4/2/21	0%		
35	Clean Up	1 day	Fri 4/2/21	Fri 4/2/21	0%	33	
36	Install Signage for Bus Route Schedule	1 day	Fri 4/2/21	Fri 4/2/21	0%	33	

Fig. 9. Schedule