Construction of a Sustainable High-Tech Greenhouse

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The purpose of this project is to assess the feasibility for farmers to upgrade from conventional farming methods to using sustainable, high-tech greenhouses. For all intensive purposes, the values presented in this paper are based off the assumption that a farmer already owns their land and can use this paper as a reference to see what it would look like if they wanted to make the upgrade to high-tech greenhouses. To assess the viability of this project my partner and I set out to complete all the preconstruction activities that a project team would need to complete for a potential owner looking to have a structure built. These various activities include 3D modeling, estimating, scheduling, and formulating a detailed business plan that demonstrates the return on investment of building a high-tech greenhouse. The combination of my 3D models, construction estimate, and construction schedule along with my partner's business plan make it easy for any farmer that wants to make the transition to using high-tech greenhouses to see: what it would look like, how much it would cost, and what the expected long term profits would be.

Key Words: High-Tech, Greenhouse, Packaging Facility, Sustainable, BIM

Introduction

The idea for this project started after my partner talked to a couple different farmers living in the Southern California region. Greenhouses have steadily become more and more popular in agriculture, and the businesses that have not yet adapted to the trend are starting to fall behind. My partner and I went down to San Diego in the spring and toured his family friends' 2-acre greenhouse and it was a cool experience seeing how profitable it is to implement greenhouses into one's farming methodologies. After getting a close look at how the greenhouse works and how much more efficient it is than other conventional soil farming methods, we saw an incredible amount of potential for growth and innovation to make greenhouses more technologically advanced than they've ever been. One of the main issues, however, is that a lot of farmers do not have the capital to invest in a greenhouse like this. So, my partner and I decided to see what it would look like to build a high-tech greenhouse, how much it would cost, and determine how profitable it would be in the long run. The greenhouse and packaging facility modeled in this paper are designed for growing Heirloom tomatoes in the Southern California area, however with a few modifications we can make this model adaptable to any other regions.

Processes

My first task for this project was to design and 3D model a packaging facility for the tomatoes to be processed and shipped out to various venders in different locations around California. As previously mentioned, this was all designed in Autodesk Revit. Figure 1a shows the floor plan of the packaging facility. There are 3 entrances around the building. The main entrance is located along the East wall, which is the employee entrance from the parking lot. The next entrance is located on the south wall in between rooms A and E, which is right next to the loading dock area and will be the main entrance for truck drivers and employees who might be coming from in from the greenhouse. Rooms A and B are both refrigeration rooms, one for Heirlooms that have not yet been processed and one for Heirlooms that have. Room E is storage/maintenance to store different tools and other materials. The third entrance is located directly next to room C, which is the packaging and processing room. This entrance is mainly for employees who are bringing boxes of tomatoes in from the greenhouse. The entrance is located in between rooms B and C because it makes it easy for employees to get to the refrigeration rooms and processing rooms which makes the overall process of handling the tomatoes more efficient. Next to the processing room is room D, which is where the office portion of the facility is located. This section is where all the records, finances, and other professional documents are taken care of and stored. Lastly is area F which encompasses the employee bathrooms. The packaging facility has a pretty open plan and all the rooms are located in their respective spots to promote efficiency. The goal is to have the entire process, from when the tomatoes are picked to when they are loaded into the trucks to be as smooth as possible.

Figure 1b shows an elevation of the loading dock. The foundation of the building needed to be raised to 5 feet to make the height of the loading dock line up with the beds of the semi-trucks. The estimated annual production for tomatoes is around 700,000 pounds of heirloom tomatoes which is why there are 3 garage doors rather than just one. This way we can unload three times as much product on shipment days.

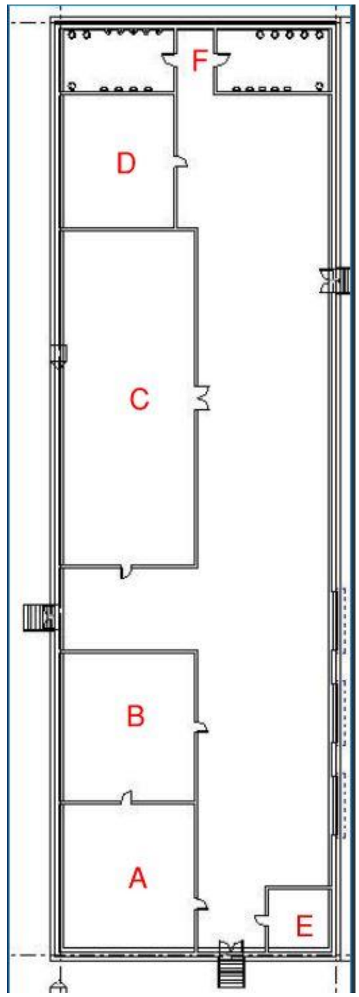

Figure 1a. Packaging Facility Floor Plan

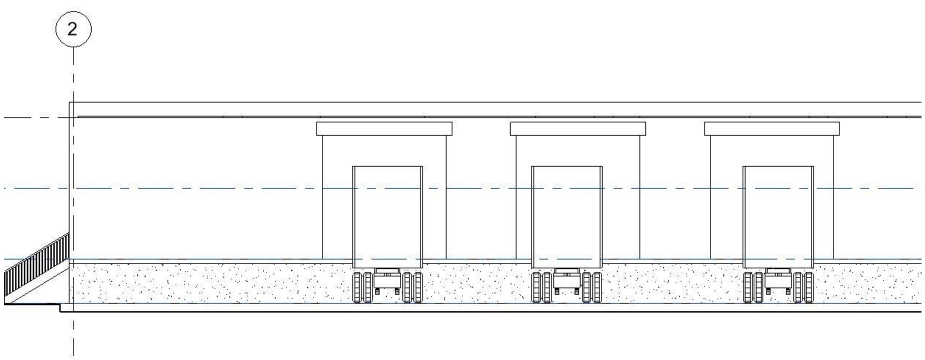

Figure 1b. Elevation of Loading Dock

Once finished with the packaging facility, my next task was to design and 3D model a one-acre, high-tech sustainable greenhouse. This ended up being the most difficult portion of the project because there was a lot more to take into consideration when choosing the different structural members of the greenhouse. The first thing I did was lay out a grid for the structural columns around where the walls of the greenhouse were going to be located, and then laid down a row of columns and arrayed that row until all the columns were in the correct location. I set the columns at 8 feet apart and 16 feet tall so that we could use 8' x 8' panels throughout the entire greenhouse to keep a consistent design. The next step in modeling the greenhouse was to add the structural beams. These beams were set at a length of 32 feet and were located 8 feet up to hold the glass panels in place. Once all these structural members were in place, I was able to install the glass paneling as well as a gravel floor which is meant to keep bugs that are able to dig underground from coming up and eating the tomatoes. There are doors on either side of the greenhouse as well as one across from the packaging facility which allows the employees to efficiently walk between each structure and not have to travel too far, especially when hauling boxes of tomatoes from the greenhouse to the packaging facility.

The next step in completing the greenhouse was to add in the structural trusses and the beams connecting them. Overall, there are 44 steel trusses extending the length of the greenhouse 32 feet apart. In order to support these trusses, the columns used that go down the center of the greenhouse are larger reinforced steel columns to support the loads imposed from the structural trusses. The last step in completing the greenhouse was installing the glass panels in the roof. Getting the slope just right was a little tricky, however using a little trigonometry I was able to find the right angle for the slope and line up the panels just right. Once the model was completed, I thought it would be cool to give a visual of where the tomatoes would be in the greenhouse, so I implemented rows of plants going all the way down the greenhouse. These rows have a 4-foot spread to allow for employees to comfortably walk in between the rows of tomatoes and pick them without any hassle. Figure 2 shows and elevation view of the greenhouse, which shows the spacing for the columns and glass panels as well as the structural trusses and beams.

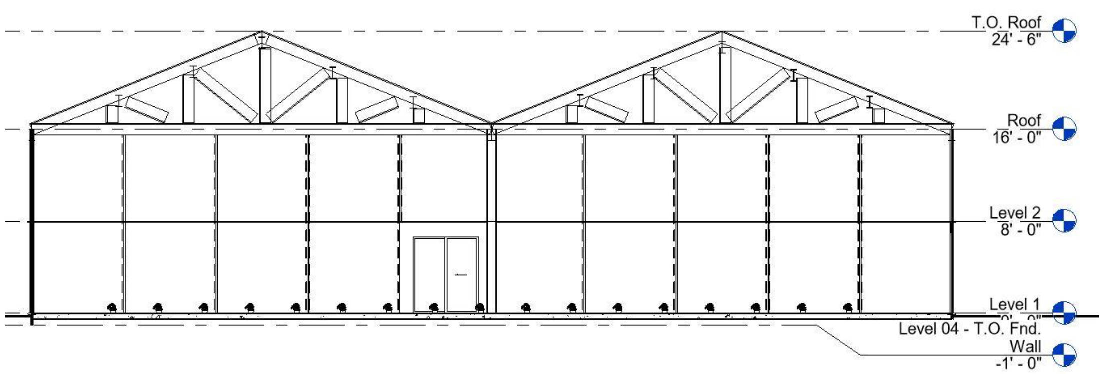

Figure 2. East Elevation of Greenhouse

Deliverables

Below are my completed deliverables, the packaging facility alone takes up a third of an acre and the employee parking lot covers a little over two thirds of an acre. This provides plenty of space for delivery trucks to come in and back into the loading dock to take shipments out without having to worry about hitting any of the parked employee or company vehicles. Figure 3 shows a picture of the completed model of the packaging facility.

Figure 4a shows the entire one-acre greenhouse model, the greenhouse will be located 12 feet away from the packaging facility on the west side of the building to allow for easy movement back and forth between buildings. Figure 4b gives a closer view of a section of the greenhouse model. When looking closely, one can see the glass panels that have been installed in the walls and roof as well as all the structural elements of the building.

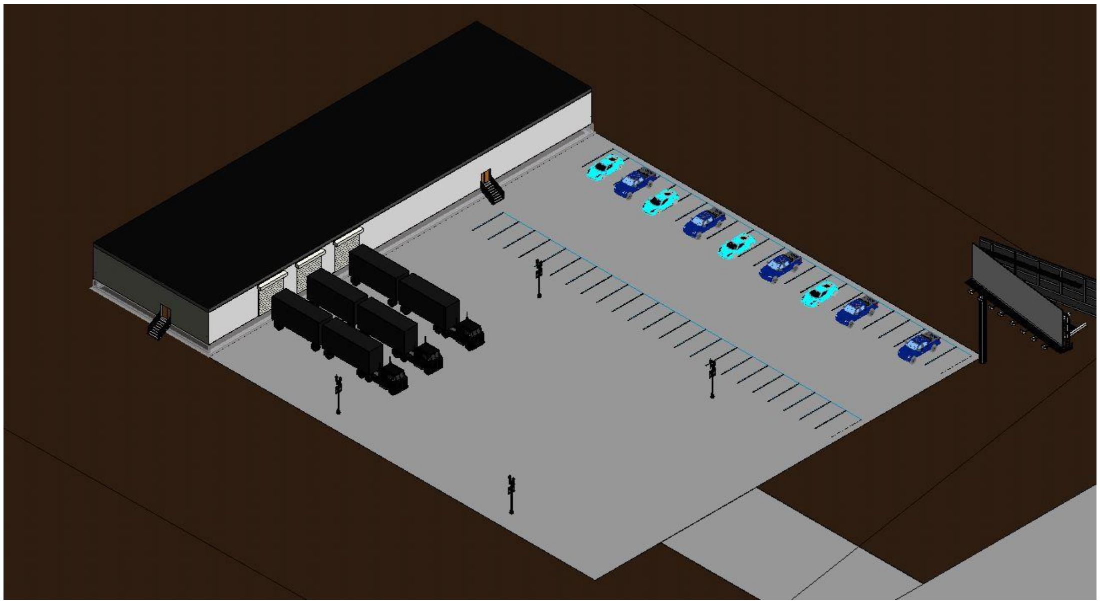

Figure 3. 3D Model of Packaging Facility

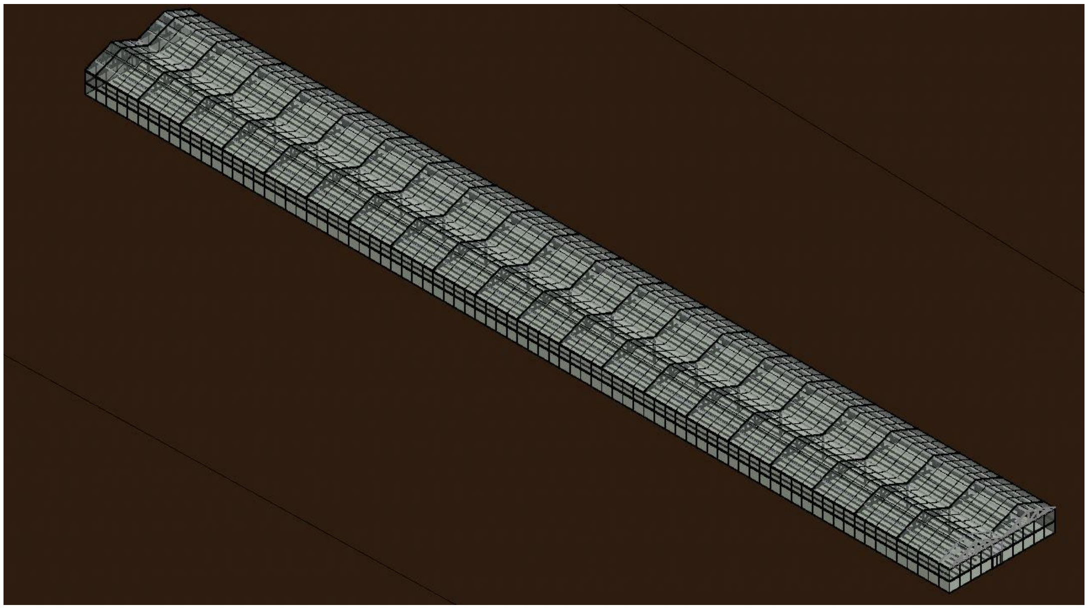
Figure 4a. 3D Model of Greenhouse

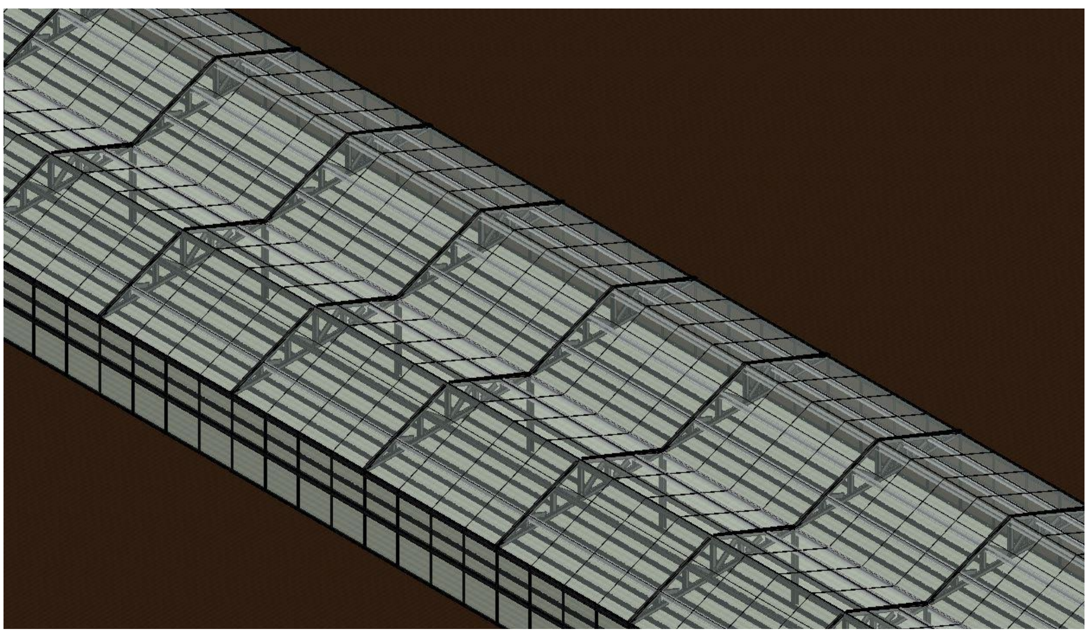
Figure 4b. Closeup of Greenhouse

Once both the models were complete, I was able to get started on the construction schedule and estimate. In order to do this I used the RS Means website to pick all the materials that I implemented in my model, calculated the square footage of the buildings and then generated a price for all the materials. Then to calculate the labor costs I used the DCD estimating book to see how much it was going to cost for the labor needed to build everything and get everything onsite. The final total for the cost of construction ended up being roughly $2.2 million for both the greenhouse and the packaging facility. Some of the most expensive costs came from the glass panels which ended up costing $216,000 for the materials alone. Figure 6 shows the final price for construction as well as gives a cost per square foot of the building.

Generating the construction schedule was a little tricky because I had to keep in mind how long the preconstruction services would typically take for a project of this size. I made a rough estimate of the amount of man hours it would take to complete each task of construction and developed a functioning construction schedule. The overall project duration is around 369 days with a construction period of 176 days. Figure 5 shows an image of what the construction schedule would look like for a prospective farmer or investor.

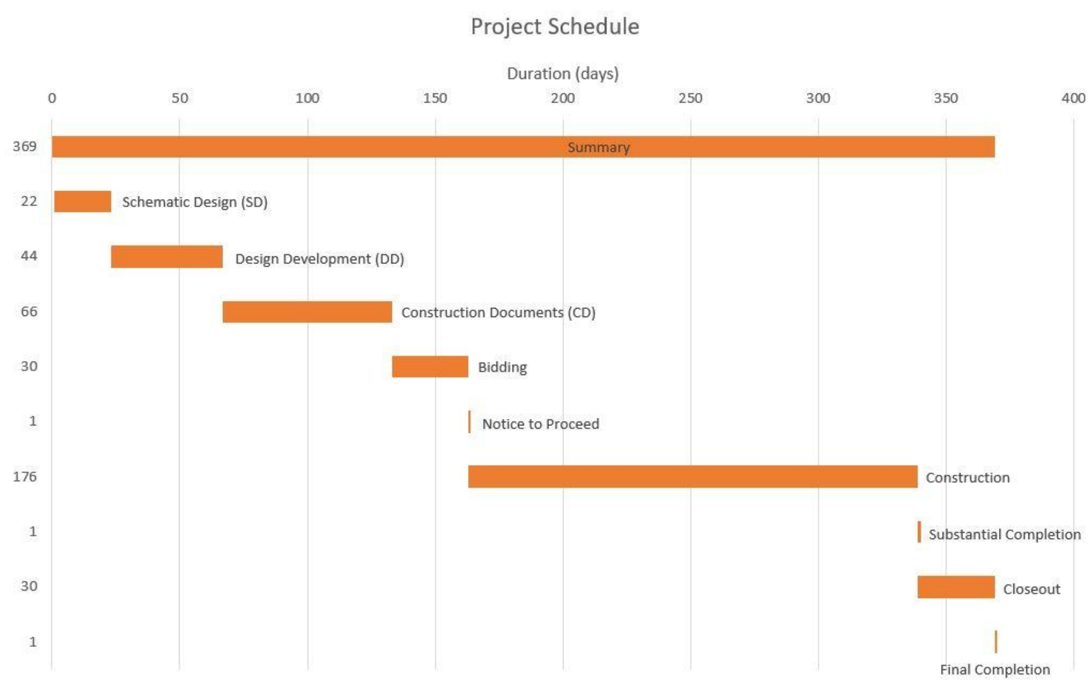

Figure 4. Project Schedule

Figure 5. Final Estimate

Lessons Learned

This project proved to be significantly more challenging than I had originally imagined because I did not realize how much goes into the preconstruction process. Making an entire 3D model is a very tedious task that requires a lot of focus and attention to detail. I learned that there is a very specific process that one must take when making a model of any building, otherwise you will not get very far at all. I also learned that there are many different materials to choose from when making your model, so Ethan and I had to go through various materials to try to find the best one for our specific project. We compared different variables such as cost, strength, and longevity to see which materials would be the best fit for the design we wanted. While touring the greenhouse we learned that paying the extra cash up front for high quality materials will save an exponential amount of money in the long run, which is why we decided to go with galvanized steel and glass panels rather than non-galvanized steel and polycarbonate panels. This will make for a much larger initial cost up front but will save so much money over the lifespan of the greenhouse because galvanized steel will not rust and corrode and glass panels do not need to be replaced.

While making the construction estimate and schedule, I learned that there is a lot more that goes into the project than just the materials. One must also account for labor needed to get all the materials to the jobsite as well as the labor needed to erect the structure. I also realized that it is not easy calculating how much time and effort it will take for the construction team to finish the project.

Conclusions

After completing this project my partner and I have concluded that building a high-tech, sustainable greenhouse is the best way for farmers to harvest crops in an efficiently and maximize their crop yield. Although the initial capital needed to get this project started is high, the long-term profits of owning a high-tech greenhouse are exponentially more beneficial than conventional farming. By using galvanized steel and glass panels rather than polycarbonate panels and non-galvanized steel, the lifespan of the greenhouse and the lower maintenance costs make this a sustainable and viable option for farmers that have the means and methods of upgrading their farming methodologies.

References

RsMeansonline.com, *https//rsmeansonline.com/square.foot.estimator*

"Architects Contractors Engineers DCD Guide to Construction Costs 2020, Volume 51", Copyright 2019, BNi Publications Inc.