

Mass Manufacturing 8x20 Tiny Homes for Low Income Housing in SLO

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The United States housing prices have been on the rise for years. This increase has led to an extremely large number of citizens in this country who are unable to afford their rent, much less buy a home. One of the many potential solutions to this problem are tiny homes. Tiny homes have been around since the 1850's but have just recently been thrust back into the spotlight. Today Tiny Homes is more than a style of housing but a movement to return to simpler times and simpler lifestyles by living out of a much smaller home. Our project goal is to test to see if these homes can be manufactured efficiently and cost-effectively enough to produce a product that is extremely affordable. As it stands today tiny homes are still too expensive to be the solution to this epidemic. We have three different business models to test to see if we can change that. The first being a Non-Profit production line, the second being a non-profit single workstation, and the final being a for profit assembly line. My team has also created a complete user guide that describes the step by step process of building a Tiny Home.

Key Words: Tiny Home, Manufacturing, Affordable Housing, User Guide, 3D Modeling

Introduction

This project began with a meeting with representatives from the City of SLO, Ryan Betz, interim assistant to the city manager, and Kyle Bell, associate planner. The local government of San Luis Obispo recently passed an ordinance that makes tiny homes on wheels legal in the county. They want a product that will get the residences of San Luis Obispo excited about the future of tiny homes, especially since tiny homes are becoming more popular as an inexpensive housing alternative.

The tiny home movement began to gain national recognition after Jay Shafer published his book "The Small House Book" in 1999. He also founded a design-and-build company called Tumbleweed Tiny House Company (Wilkinson, 2011). The company sells designs for tiny homes and offers to build homes at additional costs. This sparked a movement that began to grow quickly. In 2000, Portland Oregon opened a tiny house community called Dignity Village. The community had 43 tiny homes built using recycled material to benefit the homeless (Alex, 2019). The initial interest in tiny homes though was limited by the fact that most of these homes were illegal to live in. Then, in 2007, Oprah interviewed Jay Shafer. This interview focused on building tiny homes on trailers to avoid zoning hurdles that many people at the time were facing. This changed in 2014 when Spur, Texas became one of the first cities to be tiny home friendly. Then, popularity began to increase when the television network HGTV began the television shows *Tiny House Hunters* and *FYI's Tiny House Nation*. As the popularity began to rise, legislation needed to be changed, so the American Tiny House Association was formed to encourage and help people work with local government agencies to gain zoning approvals (Alex, 2019). In California, Fresno became the first city to pass zoning laws that benefit

tiny homes on wheels in 2016. San Luis Obispo became the second city in California to pass beneficial laws in 2019.

San Luis Obispo used to have very restrictive laws pertaining to living in RVs. While California is relatively restrictive itself, it does allow RVs to be declared an Accessory Dwelling Unit (ADU), but SLO's legislation bans that practice. The only work around to living in an RV long term in San Luis Obispo is by renting a space in a mobile home park. The change in SLO's ordinance recognizes movable Tiny Homes as separate from an RV and allows it to be declared a type of accessory dwelling unit as long as it meets the specified requirements. Some of these requirements include looking like a traditional home, being on wheels, and having less than 400 square feet of living space. That square footage allotment does not include a loft.

Steps of the Project

The first step in our senior project was doing in depth literature reviews on a surplus of information. We researched the validity of tiny homes, all the different legislations and laws in SLO county, aspects of sustainability, safety, housing construction, simple homes, Cal Coast Properties, Habitat for Humanity – San Luis Obispo, and starting a non-profit. All this information was important in getting a foundation for the rest of the work throughout the following two quarters.

Our next step in the project was coming up with multiple different solutions to this problem. We came up with 3 different solutions. For each solution we did a full financial evaluation. This included materials cost, labor costs, overhead cost, and a 5-year plan of each alternative. From this we were able to decipher which option was the most viable and made the most sense.

From here we picked the best two options, being both of our non-profit options. The first being the production line model and the next being the single workshop model. While they both have their similarities, they are two different solutions with different purposes. We decided to go with the nonprofit idea because it gave us less issues with the abundant competition.

From here we pursued the two viable options. We did this by first designing a tiny home with complete drawings and 3D models from sketch up. We also were able to come up with a ARCE-CAD sketch up of how our manufacturing facility would look like as seen in Figure 1 below. This manufacturing model gave us an idea of how much space we had to work with, allowing us to organize how our facility would be laid out in the most effective and efficient way possible.

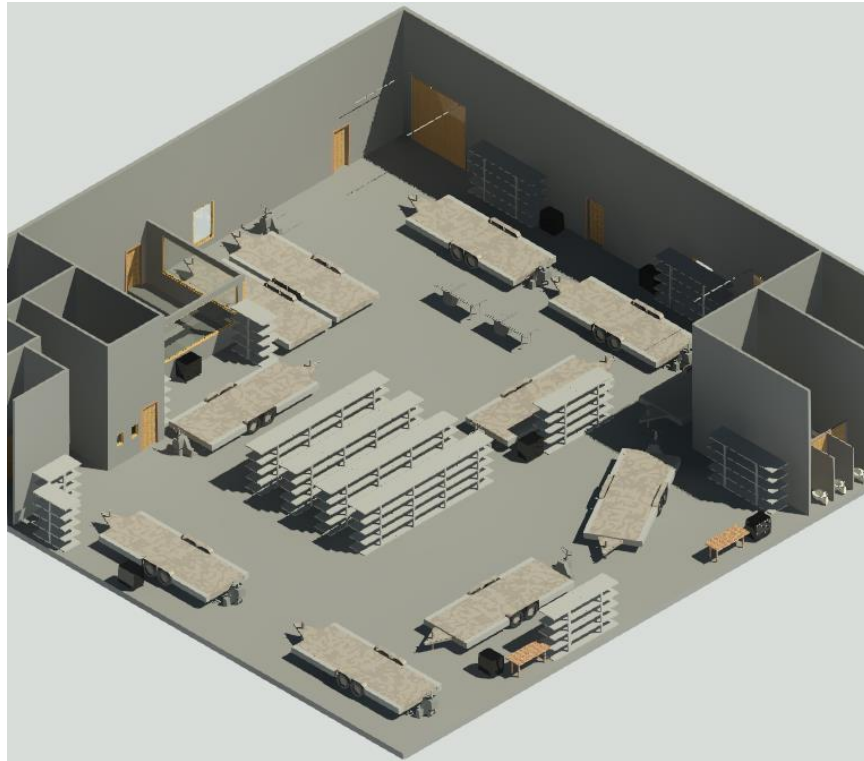


Figure 1. ARCE CAD Rendering of 3D Manufacturing Model

Finally, we constructed an IKEA style manual which teaches the buyer on how exactly to build the tiny home. In this manual we utilized our 3D model by breaking up each individual section of the tiny home to describe how to construct it. For example, we separated the framing design of the four walls and gave semi-detailed instruction on how to put them together. The final product gave the buyer a clear idea of what the 20'x8' tiny house on wheels should look like.

Deliverables

Tiny Home Design

For the dimensions of this home we went with 8 ft x 20 ft. We chose 8 feet for the width because that is the maximum width allowed on a trailer before you start getting up to commercial load status. That would of course increase shipping costs due to the need for special permits and equipment. Then for the length we decided to go 20 feet mostly because we felt this was the best compromise between price and actual livable space. Below in Figure 2 is our 3D Sketch-Up model of our Tiny Home.

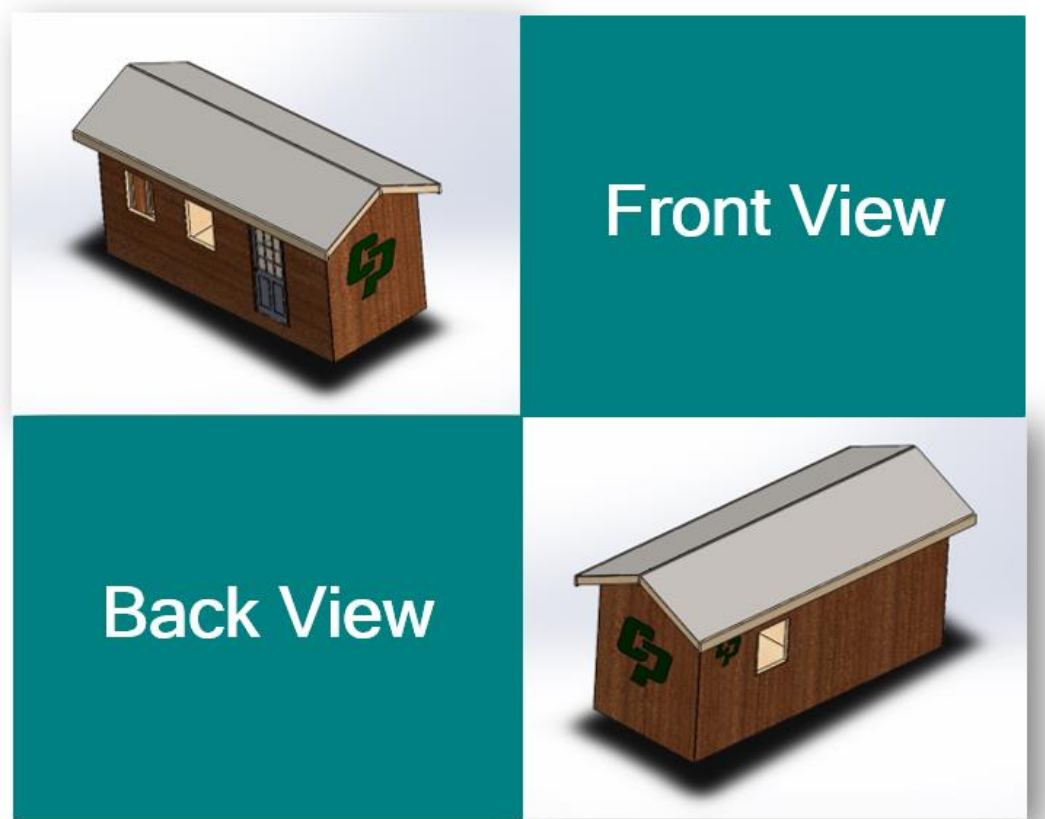


Figure 2. Sketch Up Rendering of Our 3D 8x20 Tiny Home Model

There is a small box on the neck of the hitch that is designed to be used as the utility cabinet. This is going to house the water heater, propane tank, battery, and fuse box to conserve space in the tiny home itself. The kept the rest of the exterior very simple in order to keep costs down and so we aren't training unskilled workers on too complex projects.

Figure 3 below gives a detailed floor plan of our Tiny Home Design. One important design choice we made with the floor plan is avoiding a lofted bed, so that it is accessible to everyone regardless of if they are handicapped in any way. In the kitchen we went with a simple 3 burner stove top, sink, and under counter minifridge. The bathroom butts right up to the utility cabinet to minimize the need for plumbing. There will also be a small folding table, built in dresser, shelves, and nightstand, and a full-size mattress bed. All the materials used to build our tiny home were designed to be eco-friendly, long lasting, and most importantly cost effective.

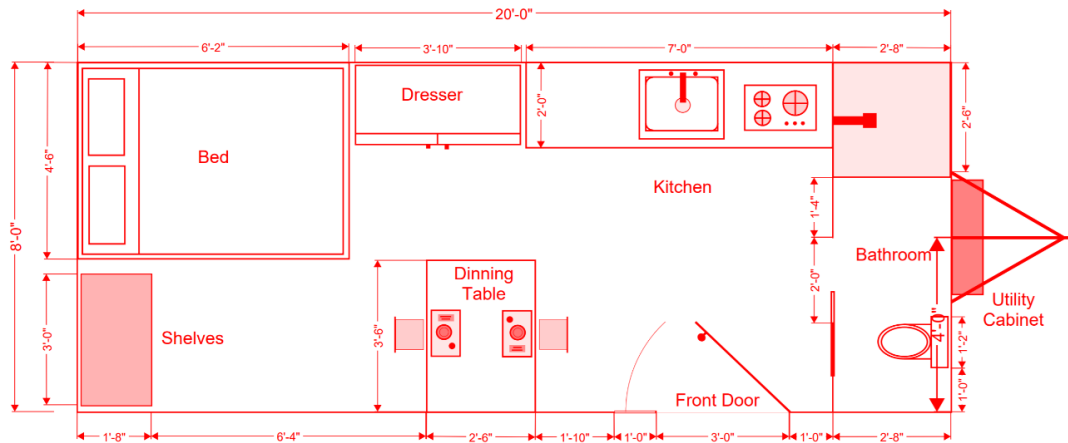


Figure 3. 2D Floor Plan of Tiny Home w/ Dimensions

Cost Breakdown

In Table 1 and Table 2 below is an itemized cost breakdown of the complete interior and exterior of our tiny home. This spreadsheet is based off the 8x6 tiny home that is constructed in the residential construction lab. It was put together to give a detailed list of the specific materials used to construct the 8x20 tiny home my team and I designed. The items that were selected are as ecofriendly and cost efficient as possible to make it affordable and reliable for the customer. After accounting for material taxes and other fees, the total price for the materials of the home is \$19,653.70. We calculated an annual cost for the for-profit production line in the manufacturing facility to be \$1,279,200, which comes out to be \$6,877 per home if we built 186 homes a year.

Table 1. Material Costs and Descriptions for Exterior of Home

General Item	Item Type	Item Description	Quantity	Cost per Unit	Total	From Where
Mud Sill	Wood	2x6-16' DF #2 BTR BORATE .17 NON GROUND CONTACT	5	\$10.00	\$50.00	Home Depot
Floor Joist	Wood	2x10 - 12' DF #2	10	\$20.00	\$200.00	Home Depot
Rim Joist	Wood	2x10 - 16' DF#2	3	\$22.00	\$66.00	Home Depot
Vents	Metal	Aluminum Sub floor Vents 4"x12"	10	\$30.00	\$300.00	Home Depot
Eave OVH HG	Wood	5/8" - 4x8 CDX Plywood	8	\$23.00	\$184.00	Home Depot

Plates, collar ties	Wood	2x4-8' DF #2	45	\$5.00	\$225.00	Home Depot
Wall Framing	Wood	2x4-92-1/4" DF #2	125	\$5.00	\$625.00	Home Depot
Headers	Wood	4x6-8' DF	6	\$20.00	\$120.00	Home Depot
Z-flashing	Metal	1/2x5/8x1x10' Z Bar Flashing	12	\$15.00	\$180.00	Home Depot
Rafters	Wood	2x6-12' DF #2	16	\$9.00	\$144.00	Home Depot
Fascia	Wood	2x8 - 10' Primed Fascia Board	10	\$24.00	\$240.00	Home Depot
Drip	Metal	2x2x10' Galv Roof Edge w/ drip (90deg angle)	12	\$5.00	\$60.00	Home Depot
Ridge	Wood	2x8-10' DF #2 BTR S4S	3	\$25.00	\$75.00	Home Depot
Rafters	Wood	SIMPRR RR Ridge Connector	22	\$3.00	\$66.00	Home Depot
Door Header	Wood	4x12 - 12' DF #2	3	\$80.00	\$240.00	Home Depot
Sheathing	Wood	3/8" 4'x8' OSB Plywood	20	\$18.00	\$360.00	Home Depot
Waterproofing	Waterproofing	9'x150' Tyvek House Wrap	2	\$160.00	\$320.00	Home Depot
Roof Sheeting	Wood	5/8" - 4x8 OSB Radiant Barrier Ply	5	\$30.00	\$150.00	Home Depot
Siding	Wood	T1-11 -4x8 Rough Sawn- (Grooves @8" O.C)	20	\$33.00	\$660.00	Home Depot
Roof	Felt	Roofing Felt 30#	2	\$31.00	\$62.00	Home Depot
Windows	Window	18"x36" single hung vinyl windows	5	\$70.00	\$350.00	Home Depot
Doors	Wood	30"x 80" 9 lite unfinished exterior door	1	\$600.00	\$600.00	Home Depot
Trim	Wood	1x4 Primed Pine Trim - 16'	30	\$18.00	\$540.00	Home Depot
Paint	Paint	Exterior weatherproof paint	4	\$25.00	\$100.00	Home Depot
Trailer	Metal	8x20 Max 10,400lbs Cap Steel Framed Trailer	1	\$5,500.00	\$5,500.00	

Table 2. Material Costs and Descriptions for Interior of Home

General Item	Item Description	Quantity	Cost per Unit	Total
Refrigerator	Smad Small Propane Fridge 3 Way Refrigerator	1	\$450.00	\$450.00
Stove Top	Atwood DV Stainless Steel Drop-in 3-burner cooktop	1	\$200.00	\$200.00
Sink & Faucet	Stainless Steel Drop In Single Bowl Kitchen Sink W/ Arc Kitchen Faucet	1	\$250.00	\$250.00
Counter Tops	Wood Slab Countertop	1	\$200.00	\$200.00
Cabinetry	Wood upper and lower finished Cabinets	1	\$350.00	\$350.00
Toilet	Nature Head composting toilet	1	\$900.00	\$900.00
Sink	Bathroom sink and faucet set	1	\$170.00	\$170.00
Bathtub	Shower Stall, Free Standing	1	\$325.00	\$325.00
Shower Head	1.25GPM Low flow showerhead	1	\$8.00	\$8.00
Misc Items	Mirror, Towel Rack, Curtain Rod & Curtain, Fan	1	\$250.00	\$250.00
Mattress	10 Inch Chime Express Memory Foam Mattress	1	\$190.00	\$190.00
Ottomans	Seville Seating with storage	3	\$40.00	\$120.00
Table	Custom fold down table	1	\$100.00	\$100.00
Plumbing	Formufit 1-1/2in x 5ft Schedule 40 PVC Pipe (Need 5 individuals)	3	\$14.00	\$42.00
Fittings & Glue	Elbows, Bushings, Caps, Tees, and Unions	5	\$12.00	\$60.00
Flex Piping	Pex tubing Plumbing Kit 1/2in x 100ft	1	\$175.00	\$175.00
Converter	12v 30a Dc Universal Regulated Switching Power Supply	1	\$20.00	\$20.00
Water Pump	Shurflo Motorhome water pump	1	\$100.00	\$100.00
Water Heater	RV Tankless Water Heater by Girard	1	\$490.00	\$490.00
Water Filter	Camco TastePure water filter	1	\$20.00	\$20.00
Fresh Water Tank	Class A Customs 46g fresh water holding tank	1	\$90.00	\$90.00
Grey Water Tank	Class A Customs 14g waste water holding tank	1	\$70.00	\$70.00
Pressure Regulator	Valterra brass water regulator	1	\$15.00	\$15.00
Insulation	R-13 Kraft Faced Fiberglass Insulation	10	\$60.00	\$600.00
Walls	EverTrue 3.5" x 8' V-Groove Pine Wood Wall Panels	15	\$12.00	\$180.00
Heater	450 watt Envi Heater	1	\$140.00	\$140.00

Electrical Wire	Southwire 12/3 Solid Romex Wire	3	\$110.00	\$330.00
Lighting				
Fixtures	6" White Round Integrated LED Recessed Lights	8	\$30.00	\$240.00
Flooring	Hardwood laminated paneled flooring	10	\$30.00	\$300.00
	36 in. x 80 in. 6-Panel Primed Premium Steel Front			
Front Door	Door Slab	1	\$120.00	\$120.00
	32" by 80" 1-Panel Shaker Interior Slab Passage			
Bathroom Door	Door	1	\$140.00	\$140.00
Paint	Basic paint	3	\$20.00	\$60.00

User Manual Guide

The final deliverable of this senior project is the user manual which gives a semi-detailed breakdown of how to construct the tiny home we designed. As this manual guide is about 40 pages long it is not included in this paper but attached as an additional deliverable. This manual begins with a quick introduction on what exactly it is designed to accomplish with a picture of what the final product should look like. The next section gives a detailed list of all the materials that are needed to build the tiny home described in the manual. This is the same materials list as seen in Table 1 & 2. Next, is the complete equipment list that is necessary to construct the house. This is a general recommendation list, so there are some alternatives tools that can be used as well. Moving on the basics. This section provides general safety tips for certain tools, equipment, PPE, and protection. Then is a general 2x4 cutting guide and a troubleshooting checklist. Now its time for the meat of the manual. For the basis of all of the sections of the house we described a step by step construction breakdown of house to build each part of the house with progress photos of the process of building. The photos show different members and dimensions of what the sections of the house should look like. The manual begins with describing the subfloor, then the framing of all of the walls, then the framing/waterproofing/sheeting of the roof, then the exterior finishing, and finally a final inspection that will make sure the home is air and water tight.

Lessons Learned

One of the lessons learned when conducting this senior project was ordinances that have been put in place on Tiny Homes in the county of San Luis Obispo. In San Luis Obispo there is clause 17.86.210(A) which states: “No recreational vehicle, camper shell, automobile or similar device shall be used for living or sleeping quarters on private property, except in a lawfully operated mobile home park, travel trailer park, campground, or safe parking facility, except as provided in Section 17.86.230 (Safe Parking) and as otherwise provided in this Section.”(City of SLO, 2019) This on its own would make the Tiny Home idea completely infeasible, as they would not be able to be considered ADUs. Just in the past year though SLO decided to change this by adding clause (E): “Recreational Vehicles as Tiny Houses in Residential Zones. Moveable tiny houses shall be considered an additional type of accessory dwelling unit, allowed as an accessory use to single-unit residential dwelling unit, consistent with Government Code, Section 65852.2, subdivision (g) which allows cities to adopt less restrictive requirements than the State-mandated minimums for accessory dwelling units. A moveable

tiny house that meets the definition in this subsection may be built and occupied as a new detached accessory dwelling unit, subject to the Director’s review and approval of the Director’s Action application if it complies with the standards of this subsection.”(City of SLO, 2019) This Clause further goes into the legal requirements a Tiny home must meet to be allowed.

Furthermore, a lot was learned about the manufacturing industry through working with four other IME students. Everything is about maximizing efficiency of production, as seen in the workflow model in Figure 4, while minimizing cost and maximizing profit. This ideology happens to be very similar to the construction industry. First, when analyzing the financials of the most viable location for a manufacturing facility, two of the most important factors is cost per SF and a 5-year income statement plan. These two pieces of information will allow a business to identify which facility is the most profitable. Another large aspect in organizing a manufacturing facility is the layout of the manufacturing line itself. You need to consider the space and organization of the construction stations. If this part of the design process is not done to perfection there can be an unknown amount of complications that rise when the facility is built out and operational.



Figure 4. Floor Plan Layout of Production Line Facility

Finally, the last significant lesson learned during this senior project was how to effectively work with students in a different major. Being the one construction management student in a group of four other industrial manufacturing engineers, I really had to apply my knowledge of the construction industry. With the combination of knowledge from both industries our group was able to conduct a very in-depth proposal for a potential business plan for a possible solution to affordable housing.

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