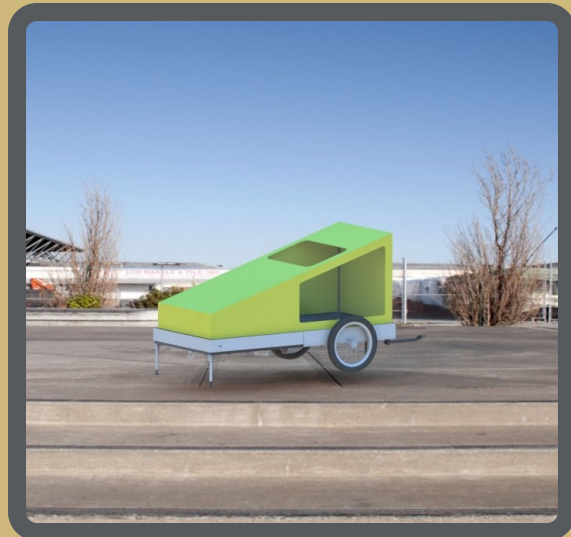


WheelHouse

Striving to Help the Homeless

An inexpensive, practical product made to significantly improve conditions for people experiencing homelessness



Engineering for Social Innovation
Senior Design Team 40



Mechanical Engineering
UNIVERSITY OF COLORADO BOULDER



Team WheelHouse is dedicated to being part of the solution to homelessness.

We also want to make bicycle camping more fun for everyone. We are doing this by making a bicycle trailer that can fold out into a single-person tent. This lightweight trailer can carry everything over rough urban or trail terrain, and is small enough to fit in the back of a station wagon. Our business model has two arms, which keeps charity as a central component - specifically, a for-profit corporation, which will feed a nonprofit organization dedicated to our mission.

Our trailer has several advantages over other models. Our larger wheel diameter means that we have excellent clearance - over 7.25 inches, almost double the height of other bicycle trailers on the market. This means that our trailer can go over terrain others couldn't. Due to its solid design it can carry much more weight than other trailers, 125 pounds. The double frame can comfortably and safely sleep an adult, and then fold up for easy travel during the day.

Background

Homelessness has always been a severe issue in the United States, and COVID-19 has resulted in a major health crisis and economic turmoil for many, the full effects of which may not be known for several years.



567,715
homeless people in the
U.S. in 2019



50%
of homeless individuals
are **unsheltered**



70%
of people experience
homelessness are
individuals



9%
decrease in temporary
housing beds over the
last 5 years

Colorado is the **#1** state for Americans experiencing severe housing cost burden, meaning they spend more than 50% of their income on housing.

California also has one of the largest homeless populations in the country. This is why we have decided to focus our efforts first locally, in the Denver and Boulder areas, then expand to the San Francisco and Los Angeles areas, and eventually to the east coast.



17
out of every 10,000
Coloradans are
homeless

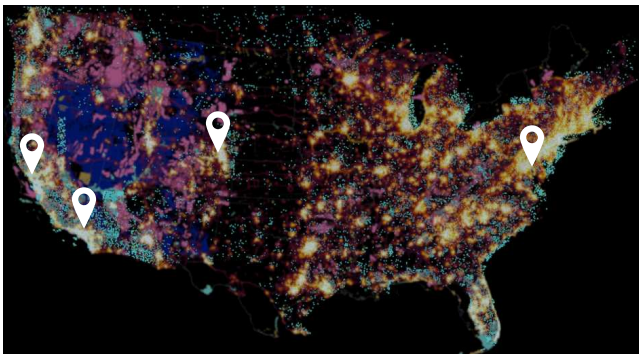


38
out of every 10,000
Californians are
homeless

Source: "State of Homelessness: 2020 Edition." National Alliance to End Homelessness, 9 Feb. 2021, endhomelessness.org/homelessness-in-america/homelessness-statistics/state-of-homelessness-2020/.

Background

In order to find the perfect target customers for our product, we took into consideration areas of the United States where biking is most common, areas with the most concentrated homeless populations, and areas with national parks and forests. This was done to cater to both the homeless market and camping/biking enthusiasts who travel cross country. Though overnight camping is not allowed in all these locations, many of them do. It is also important to note that some of these lands have older abandoned logging roads that would otherwise not be accessible by car. These locations are optimal for overnight camping. After extensive research, we decided to focus our efforts locally in the Denver/Boulder area, since most of the team members live nearby and biking and homelessness are common, then San Francisco/Los Angeles, and later expand to Baltimore and other cities along the East coast, where homelessness is most prevalent.



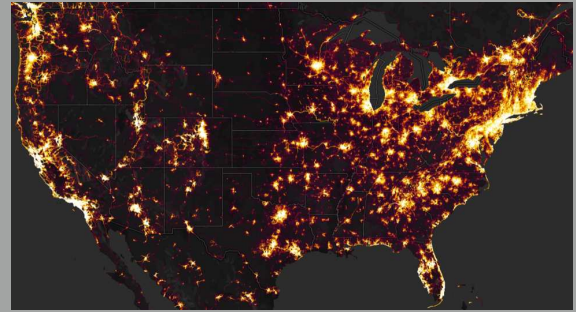
All 3 maps superimposed to represent optimal locations for our product

Sources:

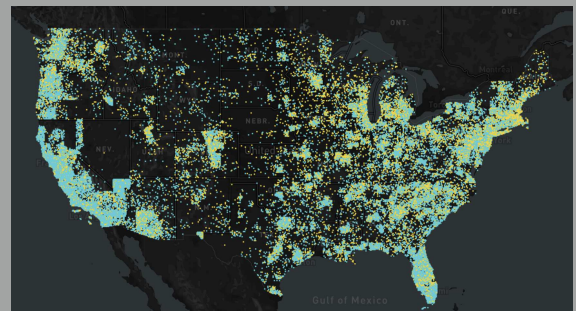
"Strava Global Heatmap." Strava, www.strava.com/heatmap#4.60/-92.03571/36.86904/hot/ride.

Understand Homelessness, www.understandhomelessness.com/explore/.

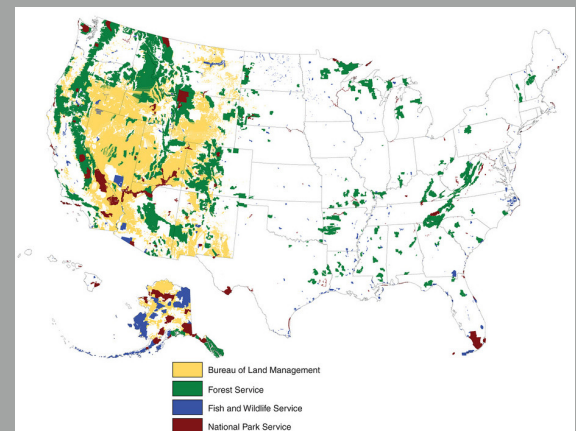
Jordan-Detamore, Greg. National Parks, Forests, Wildlife Refuges, and Other Lands: What's the Difference? 3 Aug. 2017, www.gregjd.com/blog/2017/08/03/types-of-federal-lands/.



Heat map of miles traveled by bike across the U.S.



Map of homeless population across the U.S.



Map of national parks and forest service in the U.S.



Many homeless people are forced to use any materials and resources they can find



Homeless people often have no secure location to keep all their belongings, leading to theft or animals scavenging through their belongings



Hundreds of people crowd outside Denver Rescue Mission while temperatures drop below freezing

The Problem

While there are resources available for homeless individuals, they are woefully inadequate for meeting the needs of most of these people. Homeless shelters have strict guidelines for who and what they allow in, so they are not an option for many people. People with pets, mental health issues, or physical illnesses are often not allowed in. There is also a limit on how many belongings people can bring in and they are often awoken and kicked out of shelters very early in the morning. Vehicles are costly and not an option for those who can barely afford other necessities. This results in a large portion of the homeless population using whatever that can find, like shopping carts for storage and sleeping bags for shelter. There is a wide gap in cost between having no shelter and using a vehicle for shelter, and we hope to fill this gap.

Sources:

Allen, Barry. "St. Cloud Homeless Shopping Carts - Theft or Not?" 98.1 - Minnesota's New Country, 23 Feb. 2017, minnesotasnewcountry.com/st-cloud-homeless-shopping-carts-theft-or-not/.

Curtis, Abigail. "Belfast Police Chief Believes a Foul Campsite Is Connected to Group That Gave out Tents to Homeless People." Bangor Daily News, 15 Oct. 2019, bangordailynews.com/2019/10/14/news/belfast-police-chief-believes-a-foul-campsite-is-connected-to-group-that-gave-out-tents-to-homeless-people/.

McGhee, Tom. "Denver Homeless Shelters Crowded as Temperatures Again Drop below Freezing." The Denver Post, 26 Nov. 2016, www.denverpost.com/2016/11/25/denver-homeless-vulnerable-cold-weather/.

The Solution



Prototype in expanded form

Prototype in collapsed form

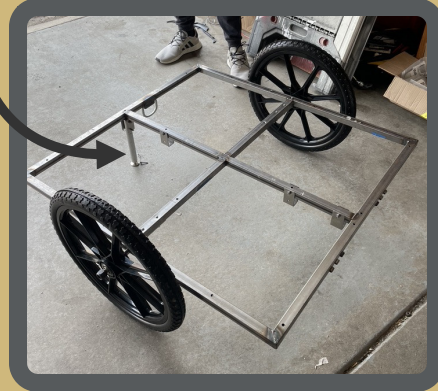


We chose to make a bike trailer because many homeless people already use bike trailers or variations of them to carry their belongings, however, the majority of these do not offer a shelter aspect. We also plan to make a deluxe model with added features and costs for those who travel and camp across the country. Our team has designed and built an affordable bike trailer that doubles as storage and shelter by expanding and collapsing and which has a pop up trailer included. We did this by finding the optimal trade-off of weight and cost with regards to material selection and design decisions. The frames are identical to simplify manufacturing processes and cost. We chose steel for the frames due to its durability and ease of repairs. The tent protects the user from extreme weather by using the same material as standard camping tents. The trailer minimizes weight so that the user can pull it on their own while also storing their belongings inside and on top of the trailer. When collapsed, the trailer has 3 feet x 3 feet x 4 inches of space inside for valuables. There are also 2 D-rings welded on the ends for a standard bike lock, zip tie, rope, or any other locking mechanism to fit through. In addition to those, there are a total of 8 smaller D-rings along the bottom of the frame for the user to attach bungee chords to and store other belongings on top of the trailer when collapsed. Our team also aims to design and build a bike trailer for the traveler demographic, those who travel cross country on bike, to have a shelter to sleep in.

How does it work?

The trailer contains two halves: the base frame and the cover frame. The frames were made from one inch steel tubing. Aluminum metal was also another contender for the frames, due to its strong but lightweight properties, but the team ended up choosing steel for a more cost effective solution. There are also tubs attached to these frames. Both the frames are identical, but the cover side tub is slightly larger than the base tub. Therefore, when the trailer is compact, the clamshell design allows the cover tub to keep water out of the inside of the trailer so the user's belongings and tent remain dry. When expanded, the support legs and tent supports can be deployed downwards and upwards, respectively. The legs and tent supports were made from 6061 Aluminum for the lightweight but durable properties. The inside of the tent is accessible by opening the door secured with a zipper. In expanded form, the laying area is large enough for the average male or female to lay down comfortably. The center support, made from the same steel as the frames, can be slid through the brackets and secured with a pin. This prevents the trailer from caving in when the user is sleeping. There are also be multiple attachment points for the user to attach their belongings, including welded on d-rings for a bicycle lock adding a sense of security. The trailer also features a hitch that can attach to a standard bicycle. This allows the trailer to be portable by hand, or by bike. We chose twenty inch wheels to ensure the trailer was capable of traveling on most terrain, while also offering six inches ground clearance to travel over steps or bumps. Overall, our design is robust and capable of enduring everyday use and giving the homeless a private, enclosed space to sleep.

1 of 3 support legs



Individual base frame



Individual base tub



Collapsed trailer supporting belongings

Testing

The WheelHouse team was able to test the trailer to ensure the trailer satisfied our design constraints. The first test was a simple dimension and weight test. The overall length limits were determined based on the average height of a person. Since the average height of a person is around 69 inches the average length of the bicycle trailer shall be 78 inches, to accommodate for the comfort of the user. Additionally, to ensure the trailer fits on standard size sidewalks, the width of the trailer shall be 42 inches. Additionally, the overall weight of the bicycle trailer shall not exceed 125 pounds to ensure that an average single user would be capable of transporting the trailer with the use of a bicycle and the weight limit also ensures that the trailer shall not compromise the bicycle structure. The results of these tests are summarized in the table below.

Dimension Testing	Dimension Restriction	1st Measurement	2nd Measurement	Pass/Fail
Length	78 in	78.5 in	78.5 in	Pass
Width	42 in	41.9 in	41.9 in	Pass
Weight Testing	Weight Restriction	1st Measurement	2nd Measurement	Pass/Fail
Weight	125 lbs	100 lbs	100 lbs	Pass

Additionally, the durability of the trailer was tested, to ensure it could support the average user. During this test, the trailer was exposed to a 300 lb force in expanded form, with the three support legs deployed. This simulated a user laying down in the sleeping area. Furthermore, since a person will be sleeping on the trailer, it was important to test that the trailer will be able to support our target user weight of 225 pounds. The average weight of a human is around 200 pounds. Adding in standard deviation, our trailer will be rated to support 225 pounds. The product will be tested with 300 pounds to ensure a factor of safety of 1.33. The team tested the deflection on six areas around the trailer with this 300 lb load to monitor the deflection. Our design constraints were made by modeling our trailer as a simply supported beam, which revealed our frame deflection should stay below 0.153 inches. The deflection was measured with a measuring tape before and during the weight loading. The results of this test are summarized in the table below.

Testing Area	Flex Restriction (inches)	Distance Before Weight Was Applied (inches)	Distance While Weight Was Applied (inches)	Change in Distance (inches)	Pass/Fail?
Base Side: Left Side, Bottom Corner	0.153	10.938	11.188	0.25	Fail
Base Side: Left Side, Middle	0.153	9.188	8.688	0.5	Fail
Base Side: Right Side, Bottom Corner	0.153	10.988	11.25	0.263	Fail
Cover Side: Left Side, Top Corner	0.153	9.875	9.875	0	Pass
Cover Side: Right Side, Middle	0.153	9	8.375	0.625	Fail
Cover Side: Right side, Top Corner	0.153	10.125	10.063	0.063	Pass

Given the limitations with our mold weights, the trailer was tested with 297 pounds. The test results proved that our trailer still needs improvement with deflection issues. The unit was able to support the 297 lbs, but did have more deflection, in most areas, than anticipated. One solution the team has come up with is to add more center support bars to better support the hinge section in the middle. The team noticed the trailer was slightly caving in, due to the hinges, but with the addition of more crossbars this issue should be eliminated.

Difficulties the Team Overcame

During the design phases of the bicycle trailer, there were many difficulties that the team had to overcome. One issue was trying to eliminate the gap that the hinges created. At first, we only designed the hinges to be on the backside of the frame, instead of underneath. This created a large gap that would have caused the sleeping area to be less supported. By moving the hinges underneath the frame, this eliminated most of the gap and allowed for more support for the user while sleeping. Another issue the team encountered was the material



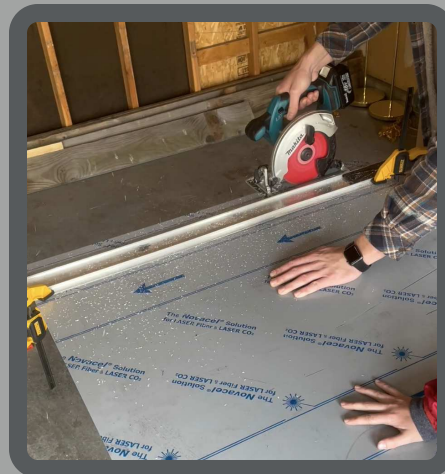
Two frame bars in the process of being welded together

selection for the two tubs. At first, the team wanted to thermoform plastic into the shapes of the tubs. This solution was simple and lightweight. However, thermoforming two tubs of this size was going to be extremely costly to do for one prototype. The WheelHouse team quickly adapted and decided to make the tubs out of sheet metal, plastic brackets, and rivets. This inexpensive solution proved to be viable for the prototype after successfully supporting the 297 pound load during testing. Lastly, given the overload of work orders in the CU machine shop, our team decided to have minimal work done, and only ask everything to be cut to size. The team decided to complete the manufacturing by buying a drill press to drill all the holes and assemble the trailer and tubs ourselves. This ended up being a simple solution to stay ahead of the timeline and to still experience a small part of the manufacturing process. Our welding was also outsourced and was graciously set up by our director Timothy Ruybal and

completed by employees from Intertech Plastics, where Mr. Ruybal works. Each time our team had to make design changes or outsource to external resources to complete the product, we adapted our timeline, to mitigate error and make adjustments for any setbacks that occurred.



The base tub in the process of being riveted together



Nick using a circular saw to cut the plate for the base tub to size

Finance

	Standard Model	Deluxe Model
Production Costs	\$100	\$250
Wholesale Price	\$150	\$375
Retail Price	\$250	\$625
Gross Profit per Unit	\$150/\$50	\$375/\$125

Note: Standard models offered for charitable purposes will be offered at marginally more than production cost

By first selling the model we designed in addition to optional features for the same sturdy frame, we can generate revenue in order to fund the design and launch of a cheaper model that can be easily manufactured and distributed to homeless people in warmer climates. Main features of the deluxe model include a water reservoir, solar power and a battery pack, a heating system, off road tires, bicycle quick release, and custom tent colors.

Charities and Organizations

While our for-profit corporation will raise funding through conventional venture capital methods, our not for profit charitable arm will work closely with charitable organizations in order to raise money and distribute our product to the people who need it most. We have been in contact with several local charities, aligning our vision with theirs, and have already received a donation of \$200 from a private individual who believes in our cause to help develop our prototype. While none have chosen to partner with us directly as of yet, we will continue to pursue these relationships. We also competed in the CU New Venture Challenge and received \$250 for making it past the first round.

**DENVER
RESCUE
MISSION**



SAINT
FRANCIS
CENTER



Meet the Team



Will Pfouts

Project Manager
B.S. Mechanical Engineering

Will has taken coursework concentrating in rapid prototyping, design for manufacturing and product development. Experience prior to school involves **management**, vehicle modification/restoration, heavy equipment and personnel logistics, and mechatronic projects for both personal and professional use. His charity involvements include working with unhoused people and early childhood education initiatives.



Nick Sloan

Manufacturing/CAD Engineer
B.S. Mechanical Engineering
Engineering Management Certificate

Nick has experience as a mechanical engineering intern at the KONG Company. Through the projects he has had the opportunity to be a part of as both a student at CU Boulder and an intern at the KONG Company, Nick has become very interested in **mechanical design**. This has led to his passion of building upon his university acquired knowledge and experiences to create or improve something that will improve the lives of others.



Lindsay Guerrero

Test/Systems Engineer
B.S. Mechanical Engineering

Lindsay has worked on many different projects throughout her engineering career at CU Boulder. She also worked in the CIEST (Center for Infrastructure, Energy and Space Testing) lab as a student technician, where she was able to apply her engineering knowledge to **real life applications**. Lindsay is excited to share her ideas with the world to help those in need.



Eric Bourgeois

Financial Manager
B.S. Mechanical Engineering

Eric has a wealth of experience in manufacturing and design. Eric has worked as an engineer under an independent Engineering Consultant developing new technologies and intellectual property for various industries, the most notable being robots and processes to clean solar panels for a company that was called Nova Solar. He prefers to work on technology with positive **social impact**.



Andrea Francu

Logistics Manager
B.S. Engineering Plus
Global Engineering Minor
Engineering Management Minor

Andrea has experience as a mechanical engineering intern at Fuji Xerox Research Labs as well as **designing and manufacturing** several projects at CU Boulder. As an Engineering Plus major, her emphasis is in Mechanical Engineering and her concentration is in Engineering Management. She is enthusiastic about any project that can help those in need.

Team Mentors

Our team has had the opportunity to work with mentors that have allowed us to greatly increase our quality of learning over the course of this project and increase the quality of our prototype. Our team has been especially appreciative given the format of our project due to the COVID-19 pandemic. These individuals that we would like to give a huge thanks and credit to are our director Tim Ruybal, our client Dario Atallah, and our Professor Dan Riffell. Tim Ruybal has been involved in every step of our design process and, due to the format of our project, has offered to us his personal tools, equipment, and most importantly time in order to ensure that we had the opportunity to build a functional prototype even if it was off campus. Dario Atallah has been invaluable in helping us design our product and company in a way that allows us to reach our target markets effectively. Last but not least, Dan Riffell has led us through every step in the design process. From overviews of project design best practices to holding individual meetings with our team on his own time to go over technical drawings and product design, Professor Riffell has greatly enhanced our design project experiences.



Tim Ruybal
Team Director
Senior Engineering Account Manager,
Intertech Plastics



Dan Riffell
ESI Professor
Scholar in Residence,
University of Colorado Boulder



Dario Atallah
Team Client
Senior Data Engineering Consultant
Boulder, CO

Team WheelHouse: Making the best camping bicycle trailers on the market.

Team WheelHouse is dedicated to helping the bicycle camping community AND unhoused people at the same time. We are doing this by making a product that is suitable for the tough outdoor environment of backwoods trail riding, and giving back to the community with a version suitable for homeless charities.

If you are interested in this product or learning more about homelessness in America please contact us at andrea.francu@colorado.edu. We will continue working on this project after the end of this school year. Be a part of our adventure together!

