Carron

The all-terrain cart for
transporting material to bothies

Project Summary

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Product Overview

What

A lightweight, foldable, two-wheeled cart designed to be pushed or pulled. Intended to transport building materials to bothies.

Who

Originally designed for the Mountain Bothy Association, *Carron* could be used by anyone who needs to move material along rough trails.

Where

Off-road. Specifically designed for traversing soft, boggy ground and mounting over large obstacles. Can fit in a car boot for transport to site.

When

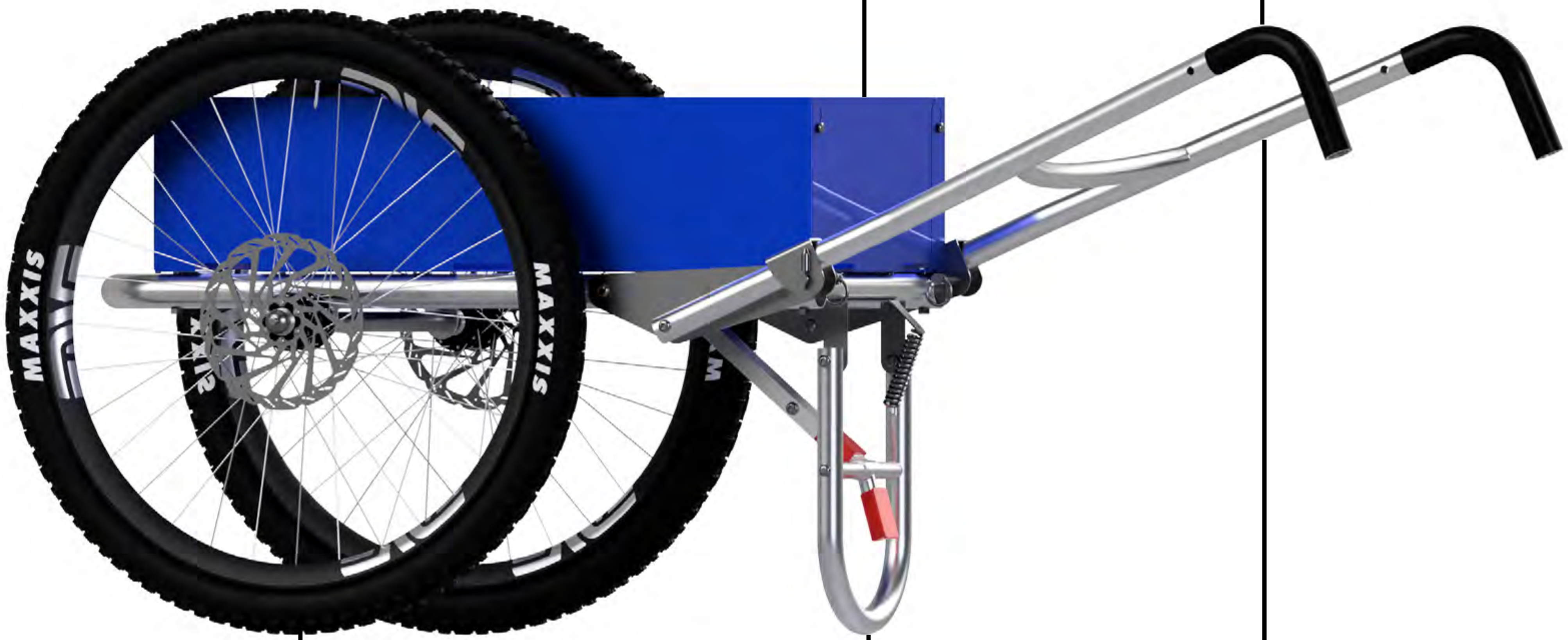
Intended for minor work parties and regular maintenance jobs, when a few people need to transport a small amount of material.

Why

Current solutions are too expensive or inadequate at traversing the terrain. *Carron* is designed to offer a great solution at an accessible price.

Removable container walls allow transportation of long items

Curved handles allow the cart to be easily pushed or pulled



Standard mountain bike wheels secured with quick-release axles

Folding leg can be easily deployed and retracted with foot paddles

Folding handlebars for portability. Secured with a sword lock pin

User Journey

1. Drive to site

Folded product fits in the boot

2. Arrival at car park

Assemble and load up the product

3. Start walking

Kick the leg up and start moving

4. Travel to bothy

Traverse rough terrain with ease

5. Arrive at bothy

Kick the leg down and unload

6. Return to car

Follow steps in reverse!

Initial Research

Expert interview

Interviewed one of the thirteen Maintenance Organisers of the Mountain Bothy Association; those responsible for maintaining bothies. Learned that helicopters are used where absolutely necessary, but **the charity has very limited means to hire specialist motorised solutions**.

What is being carried?

Analysed a building quotation from a previous renovation project provided by the charity. Found that:

46%
of all weight was transported in 25kg bags.

23%
of all weight was in the form of planks.

Modelling the user current journey

Travelled to Carron bothy with two bothy-goers, a wheelbarrow, and a 25kg bag of cement. Discovered that wheelbarrows are not designed to travel over rough terrain. **Pulling is often better than pushing** when encountering large obstacles, but wheelbarrow handles are uncomfortable to pull on. **The wheelbarrow was also difficult to fit in the car.**

User interactions

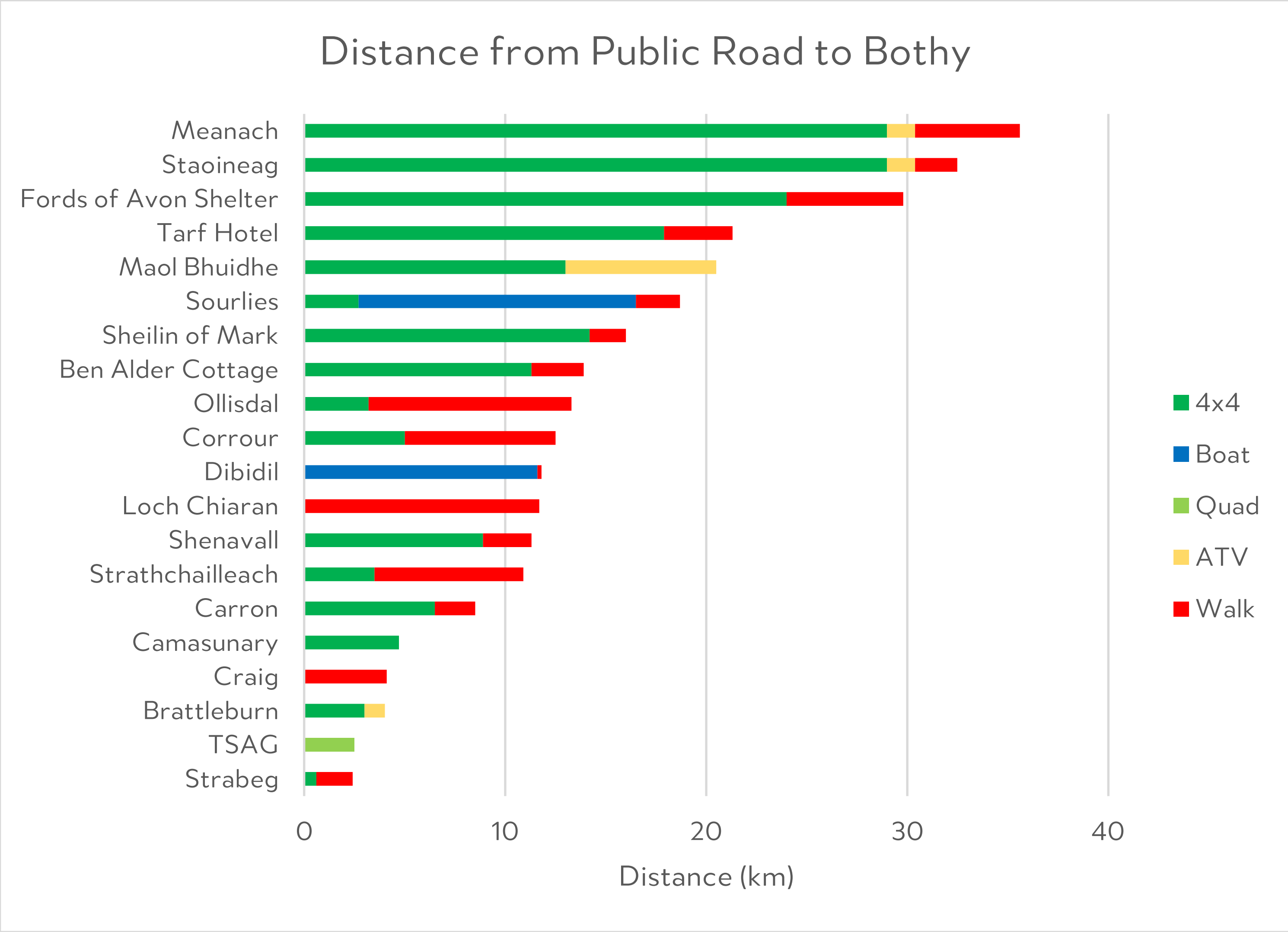
Spoke to regular bothy-goers and charity volunteers on social media. Transport of materials was the most common problem mentioned. Many regular bothy-goers are deterred from volunteering solely due to this challenge.

Where is it going?

Performed an audit of 20 bothies to document the distance of the path, the type of terrain encountered, and the required mode of transport for each. Found that:

3.5km
Average length of walking segment

60%
of bothy paths require manual carrying



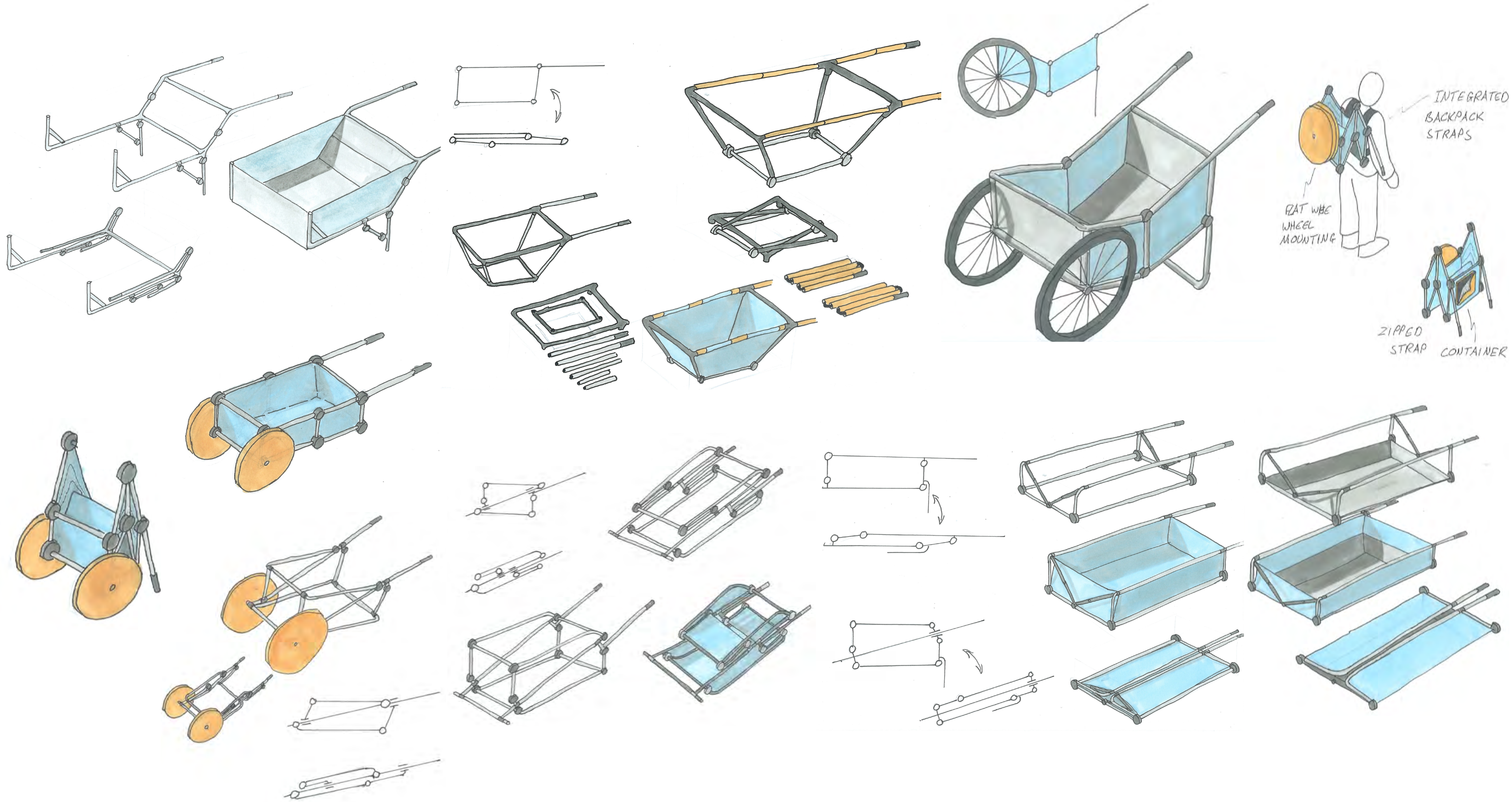
Concepts

Generation

Considered a range of early concepts including drones, hot air balloons, caterpillar tracks, and more. Later concepts tended towards a folding frame to possibly allow carrying on back and fitting inside a car.

Evaluation

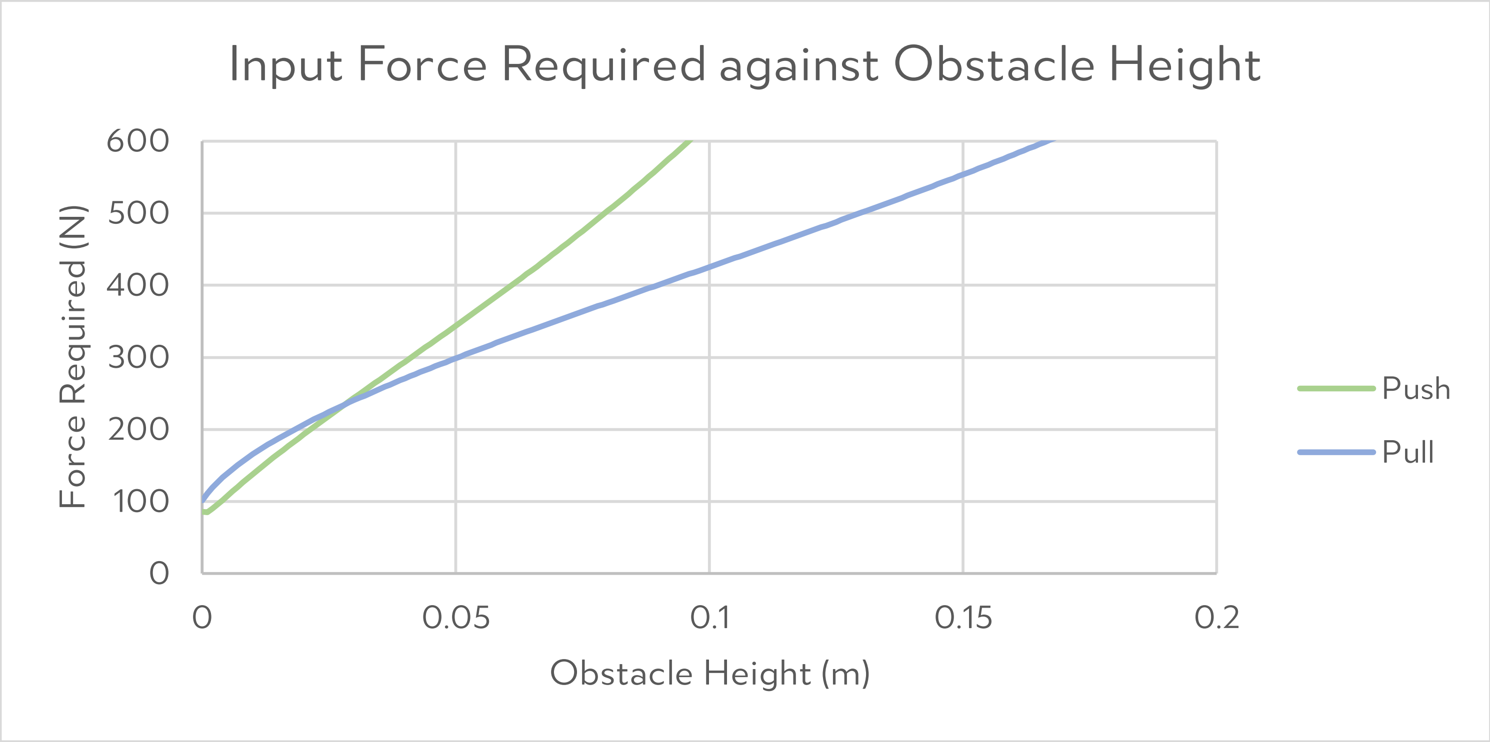
Concepts were evaluated against a range of criteria and **a concept was selected with an independently folding handle and leg**.

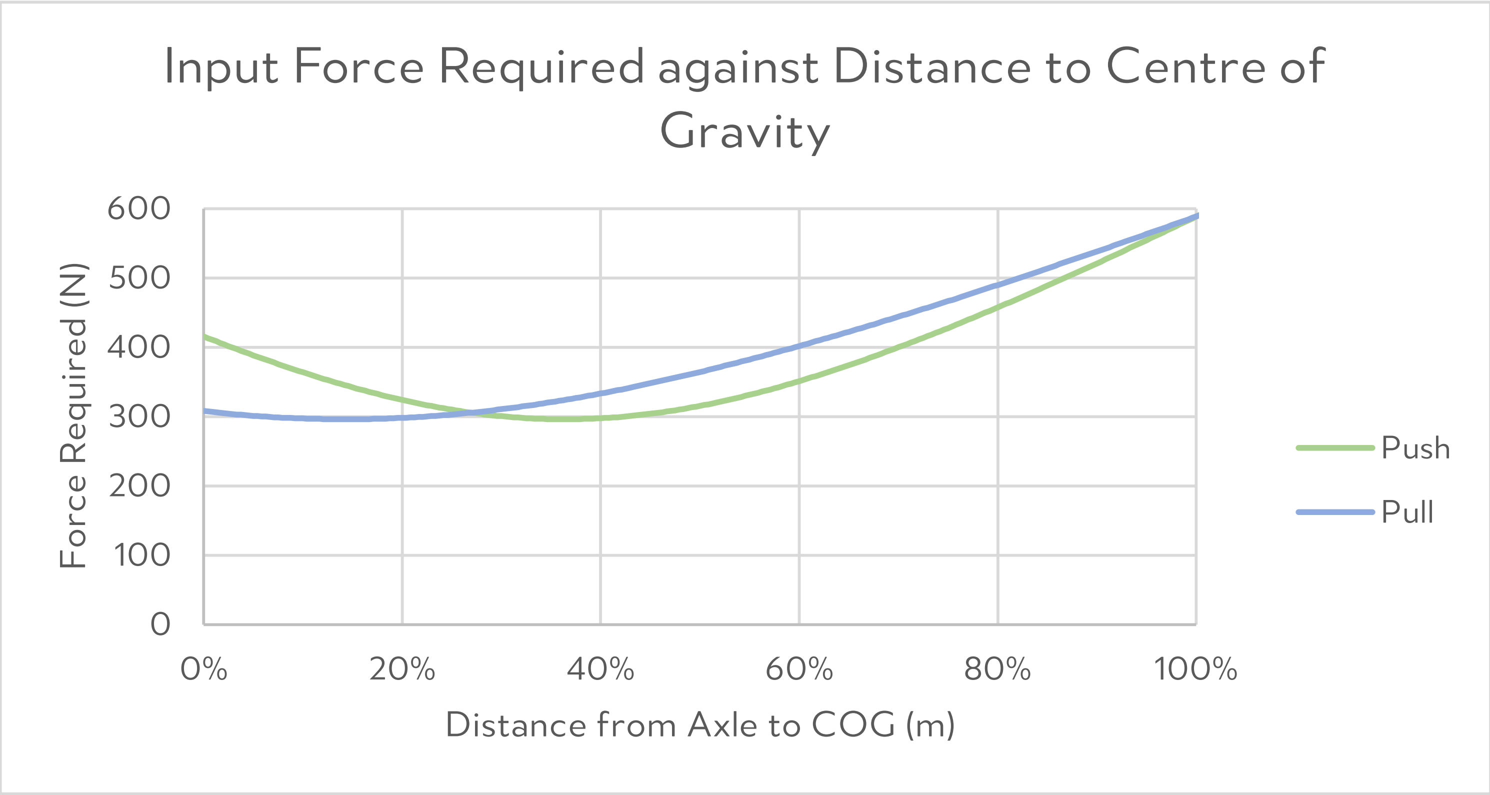


Human Factors

Optimised cart dimensions

The size of the wheels, length of the handles, and position of the axle were all determined through calculation. Dimensions were chosen which minimise the force required from the user to move the cart over an obstacle or up a hill.





Push or pull

The curved handles allow the product to be easily pulled. Testing and calculations show that mounting large obstacles and travelling through soft ground is easier while pulling.

The handle diameter was set at 33mm for maximum comfort over long distance. The height of the handles was set to 675mm to allow shorter users to easily lift the leg off the ground. The single-axle wheel layout means the handles automatically adjust to the user's height, and the retractable leg means it cannot collide with obstacles along the path.

The two-wheel design provides lateral stability, reducing the strain in the user's arms. This is especially apparent when pulling the product.

Versatility

Providing options to the user

Versatility is at the heart of *Carron*'s design. A prototype was constructed and presented to 20 members of the MBA during an annual meeting for feedback, including all 13 Maintenance Organisers. The Maintenance Organisers expressed a desire for the product to serve as a platform onto which other functionalities can be added.

Removable walls

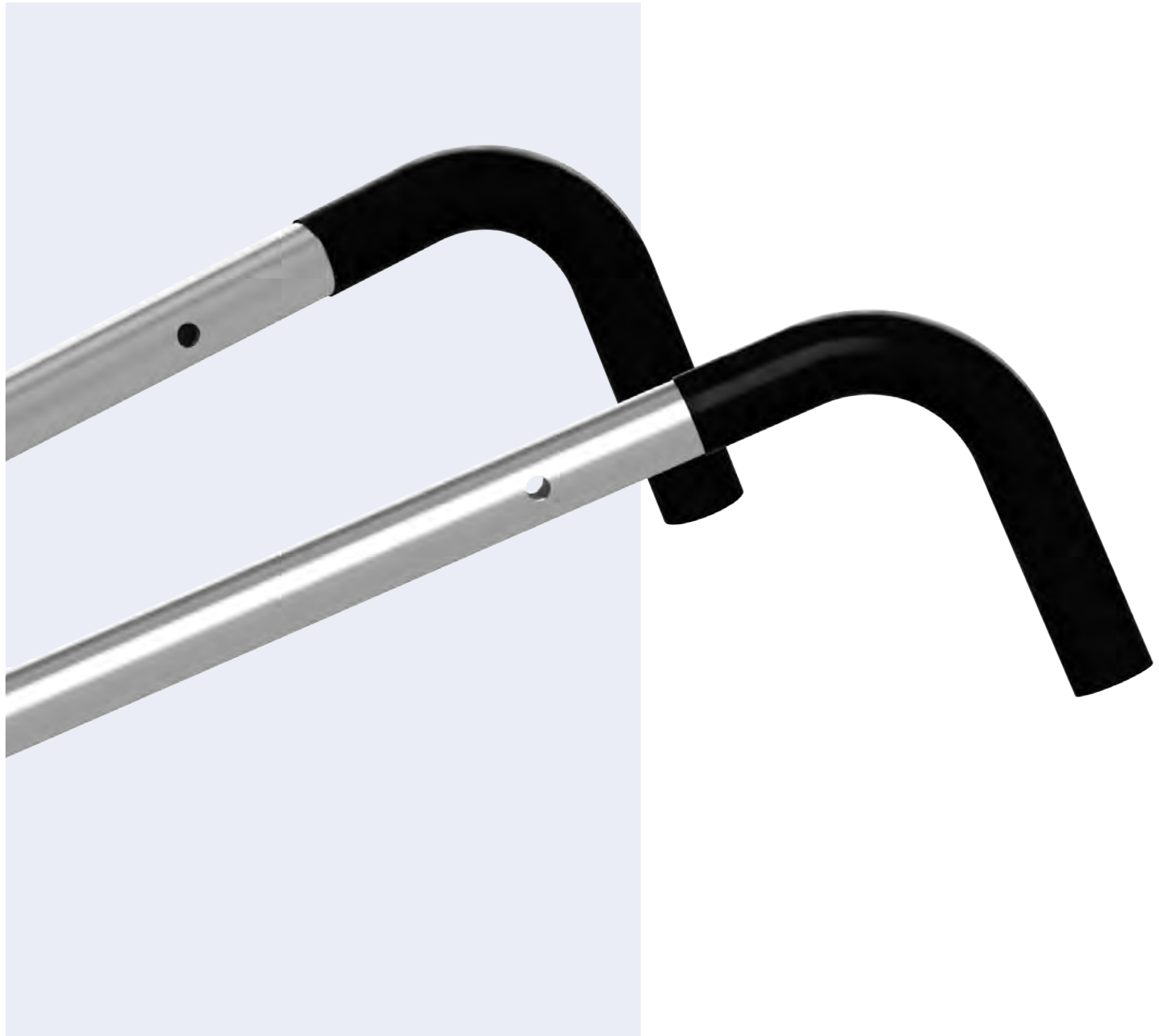
The removable walls of the container creates a flatbad, allowing the user to carry a wide range of materials. Cutouts in the container provide access to the frame, allowing materials to be tied down with rope or straps.

Standard wheel connection

The 20mm axle makes it compatible with existing mountain bike wheels. The user can change the type of bike wheel used. Poor terrain would benefit from wider tyres, while narrow tyres would be more efficient on long, well constructed paths.

Multiple handle options

The frame protrudes at the front of the cart, allowing it to act as a handle for a second user. It also acts a mounting point for a rope for pulling, as this is a common technique used by the MBA. Holes at the handles allow the attachment of a harness.



Folding Leg

The need for folding

Modelling the current user journey with the wheelbarrow showed that the legs tended to collide with rocks and other obstacles along the path. It was decided a single, retracting leg would address this issue and allow the user to pull the cart without worrying about placement.

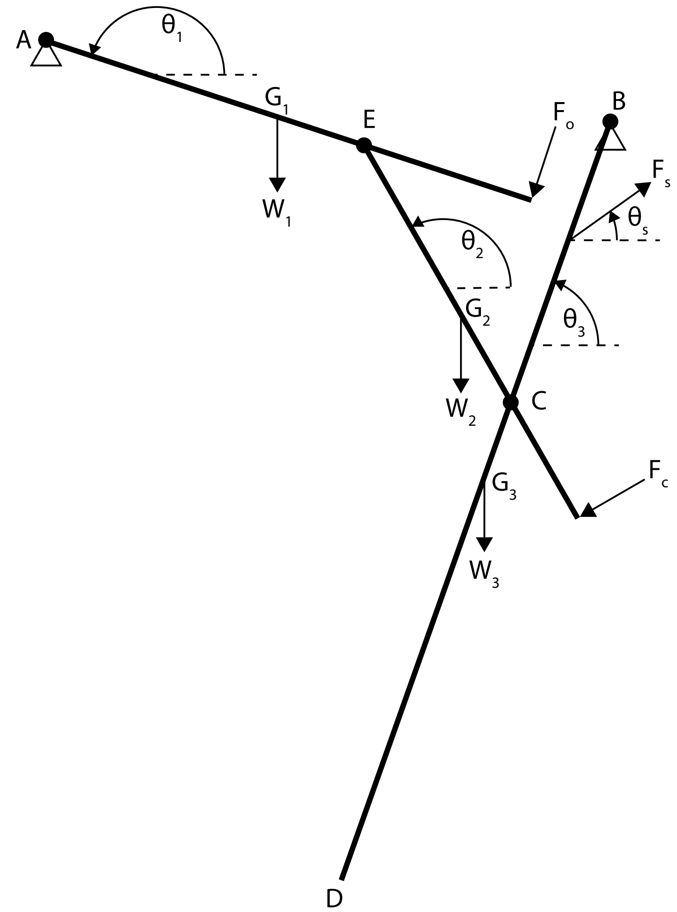
Deployment and retraction

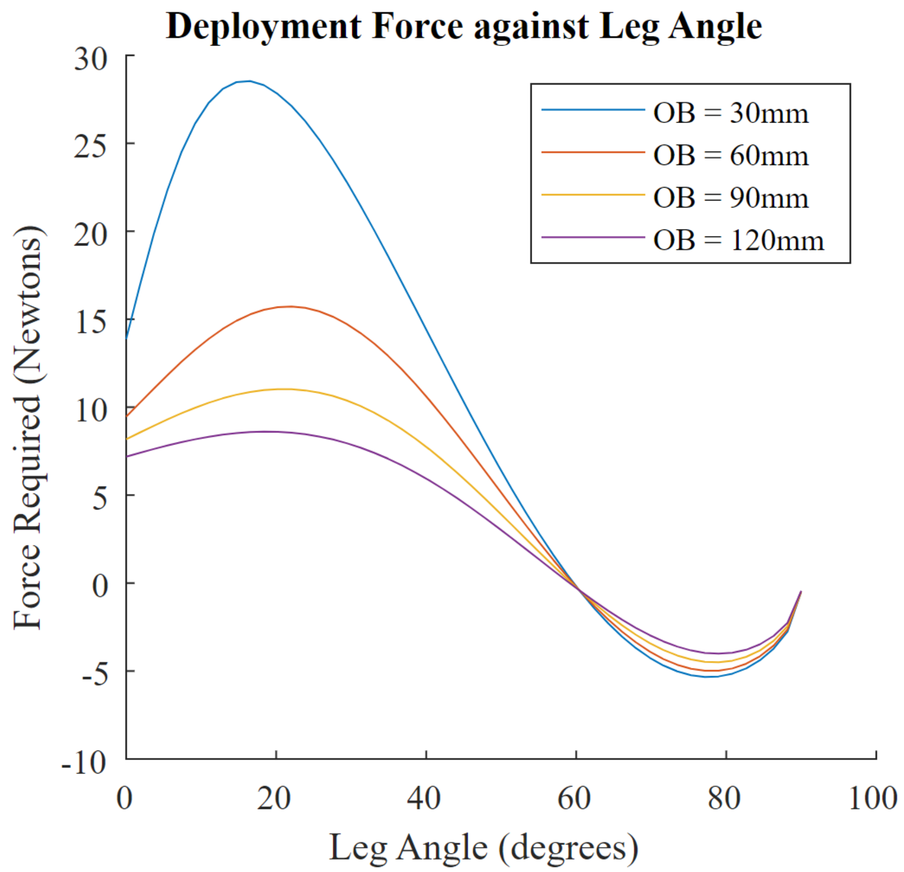
A spring is positioned to turn the leg into a bistable mechanism, meaning it will hold its position while deployed and retracted. The user would retract the leg as they begin to move the product, so it was important they were able to do so while keeping their hands on the handles. It was decided that foot operated paddles were the best solution.

Optimising for easy deployment

The deployment foot paddle has less mechanical advantage than the retraction paddle, so it was important to ensure it would still function as intended.

The leg was modelled as a four-bar linkage and static force analysis was performed to understand how each dimension affects its performance. The results from this calculation, and testing of a full-scale prototype were used to adjust the dimensions and reduce the deployment force by 50%. Undesirable reaction forces on the frame were also minimised.





Structural Integrity and Materials

Folding handle

The frame and handle are responsible for resisting the bending moment applied by the weight of the load. The hinge of the folding handle was designed to withstand carrying a 110kg load with a safety factor of 2.

The frame/handle assembly was initially modelled with hand calculations as a simply supported beam with a point load, as this enabled the rapid comparison of different tube sizes and materials. **These calculations led to the decision to use 6082 alloy aluminium tubes throughout**. By increasing the diameter and decreasing the wall thickness of the tubes, their stiffness is increased without adding material. This approach was used to specify a **40mm diameter for the frame tube**.

The handle was designed to unfold from below so it butts against the sheet metal component, before being secured in place with a locking pin. This design ensured the pin was only required to prevent the handle from folding, and did not need to resist the primary load acting on the structure.

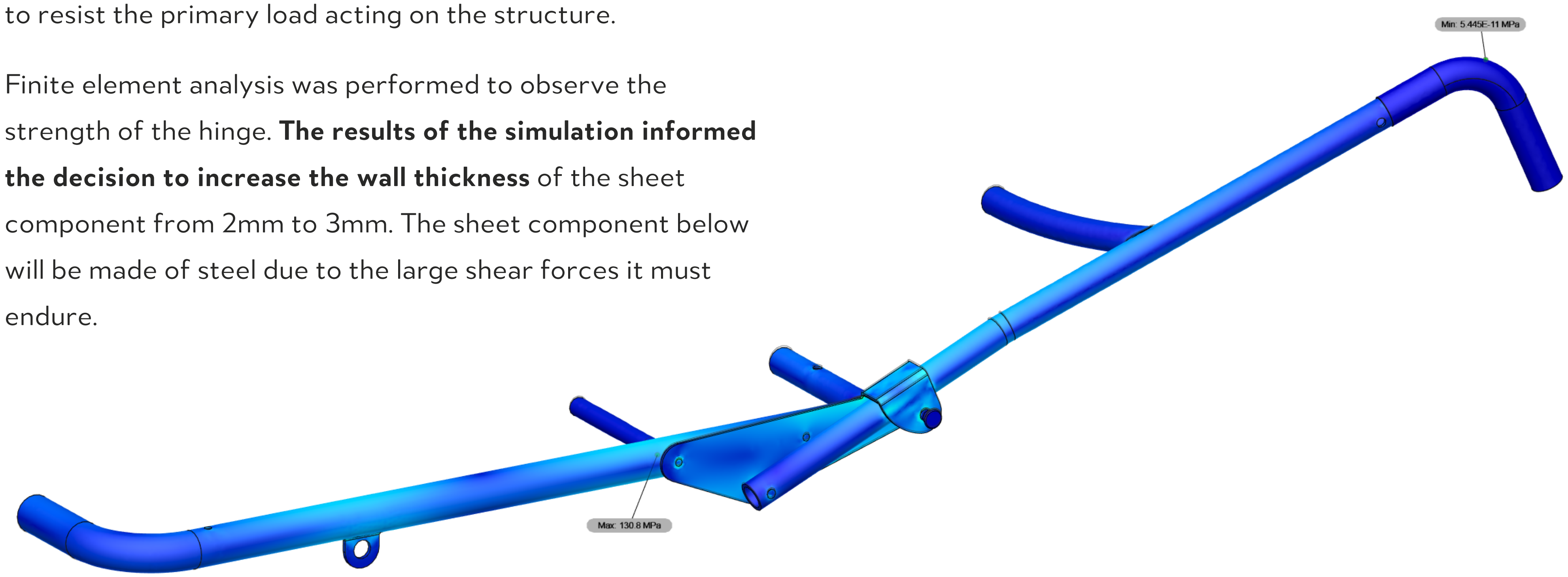
Finite element analysis was performed to observe the strength of the hinge. **The results of the simulation informed the decision to increase the wall thickness** of the sheet component from 2mm to 3mm. The sheet component below will be made of steel due to the large shear forces it must endure.

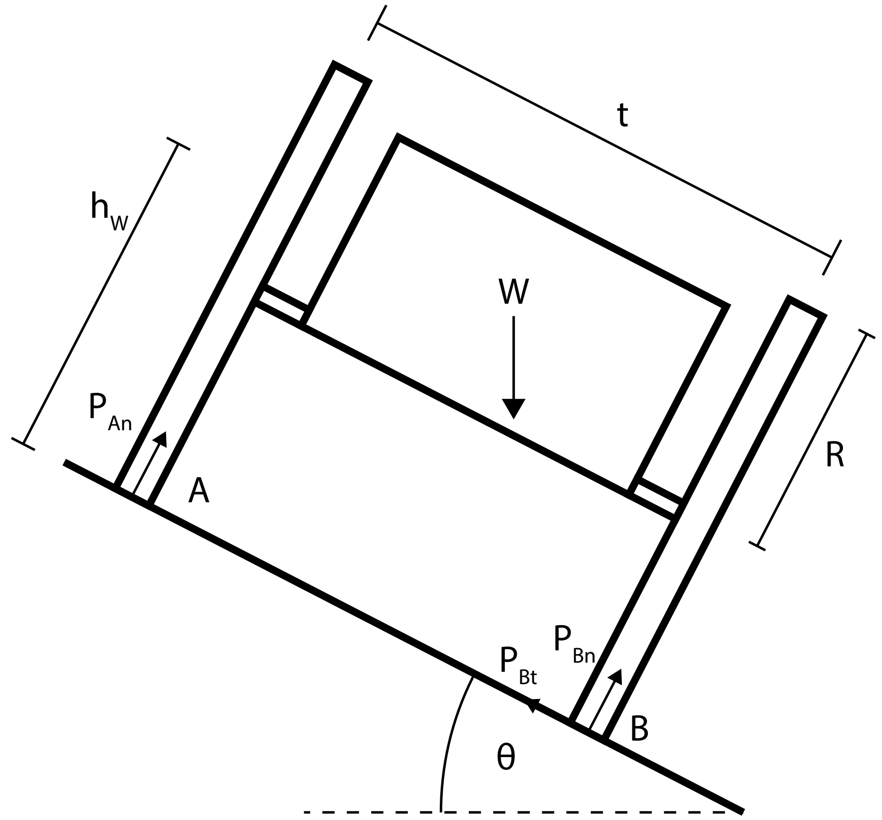
Forces acting on the axle

The axle must resist a number of forces acting upon it, the largest being the lateral force caused by traversing a slope.

This was demonstrated when testing the first full-scale prototype. 5mm diameter threaded rods were used as axles, and they bent almost immedietely.

This load case was drawn as a kinematic diagram and the axle was modelled as a cantilever beam to approximate the peak stress acting on it. This calculation led to a specification of a 20mm diameter tube with a 3mm wall thickness, constructed of AISI 4130 alloy steel.





Manufacture

Standard parts

Standard parts were used where possible, in the interest of reducing the cost of manufacture at a low scale of production and improving repairability. The axle accepts standard bike wheels and the locking pins that secure the folding handle are used in many other applications.

Repairability

Semi-permanent fasteners are used widely to allow the user to easily repair or replace individual components. Welds are only used at key load-bearing joints where disassembly is not required to remove other parts. Threaded end tube inserts are used where disassembly could be required.

Designed for manufacture

The product has been designed to be manufactured at a low scale of production. This requirement led to the container employing a bent sheet metal construction, rather than a deep-drawn construction. Tube bending is used over welding where possible to reduce manufacturing time. Most other components could be manufactured in a regular workshop.