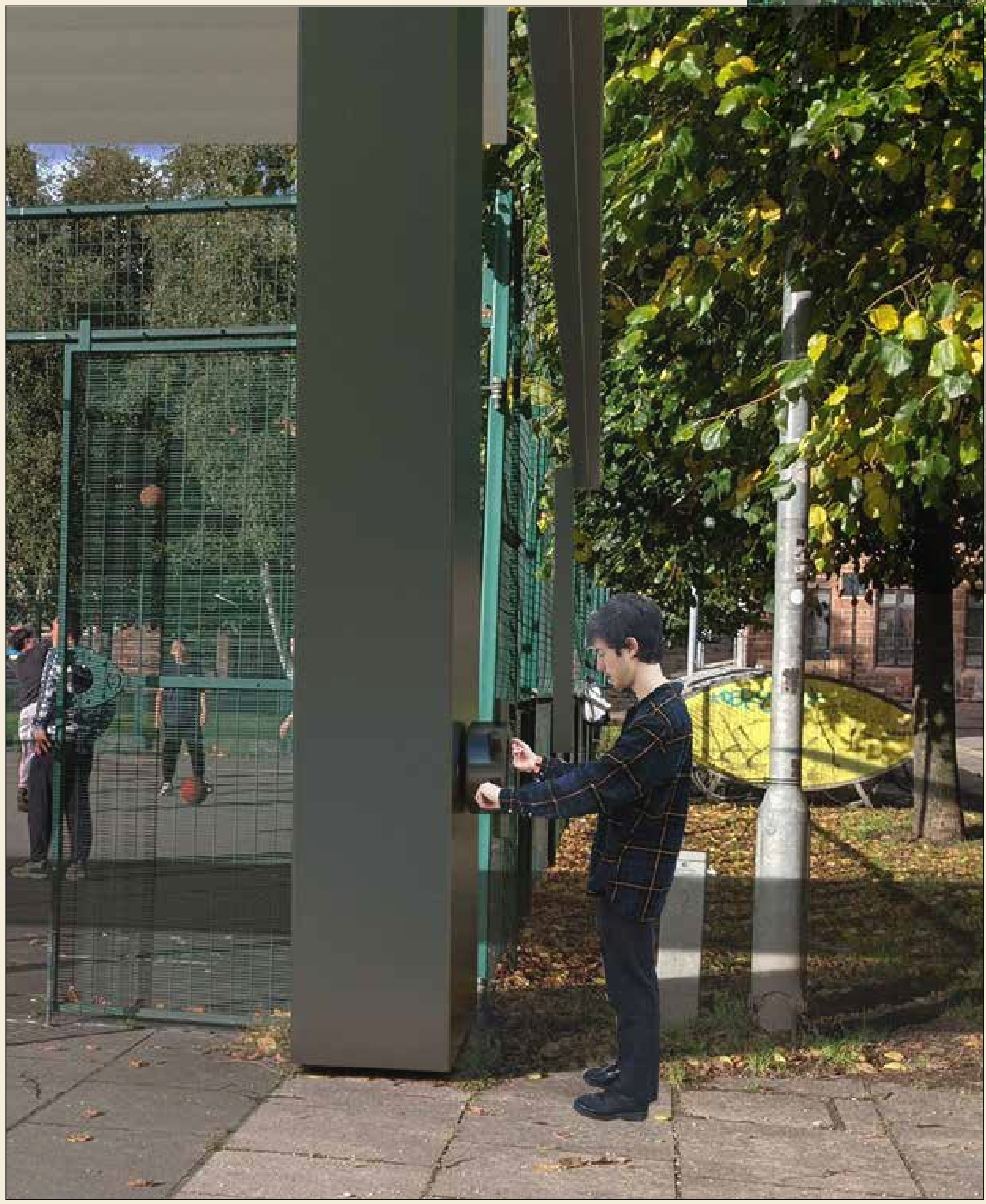
canopy

Don't let the rain ruin your game.

A retractable shelter designed for outdoor public sports facilities.
Rain or shine, sports can be accessible for everyone.



Carmen Tran - Final Year Project MEng - 10 Page Summary

research

“Outdoor basketball is much more popular due to the rise of 3v3 basketball - the number one urban sport in the world”

“the usage of outdoor public space increased due to the pandemic as indoor sports facilities closed”

“access to outdoor basketball in Glasgow is extremely limited as it rains 170 days a year”

methods

users
As a basketball player myself I had my own preconceptions about the issues I have experienced playing outdoor basketball. It was important for me to speak current users of outdoor courts as well as non-users to discern the reasons why these spaces go under-used.

In a survey sent to the men’s and women’s basketball clubs at Glasgow University, I uncovered a range of problems that I hadn’t considered, including lack of privacy and lack of scheduling.

An overwhelming theme in the survey and conversations I had with users pointed to the Scottish weather being a huge deterrent to whether or not someone could access the basketball courts.

focus group
As part of my research phase I conducted a focus group consisting of highschool students from an area with a local outdoor basketball court. Many of the group had either an interest in sports or had first hand experience with playing outdoor basketball. One issue raised by the group was a lack of game balls to play with at the court, meaning one student had to be inconvenienced by bringing it to school so they could play after studying. Weather conditions were also among the issues raised by the students, with some even suggesting a cover over the court.

observation
During the research phase, I spent time down at my local court at different times of day and during different weather conditions. I learned that it wasn’t the cold nor the dark that deterred users, but the rain which created a dangerous slippery surface.

From observation, I also learned how different users interacted differently with the space. Younger children (usually accompanied by adults) would use the courts to mess around and play casually. High school aged children tended to run drills or train as this age bracket usually had a club or school team that they trained regularly with. University aged students used the court to play more serious pick up games, as they don’t have a club team the outdoor court is the only place they can play unless they pay to book a hall. Older men used the court to play more organised games, they use a group chat to organise sessions but invite strangers and other users to join in.

These insights meant that the solution had to be inclusive of all users of the court.

design brief

existing solutions

Street space

Creates indoor/outdoor feel as there are open sides. Owned by the facility.

Copri systems

Telescopic retractable shelters for sports facilities, creates a completely indoor space. Owned by the facility.

Zapp

Retractable awnings for the restaurant industry. Motor powered and owned by the establishment.

Wimbledon Centre Court

Large scale retractable roof over Centre Court. Huge amount of supporting structure needed due to the size.

market intent

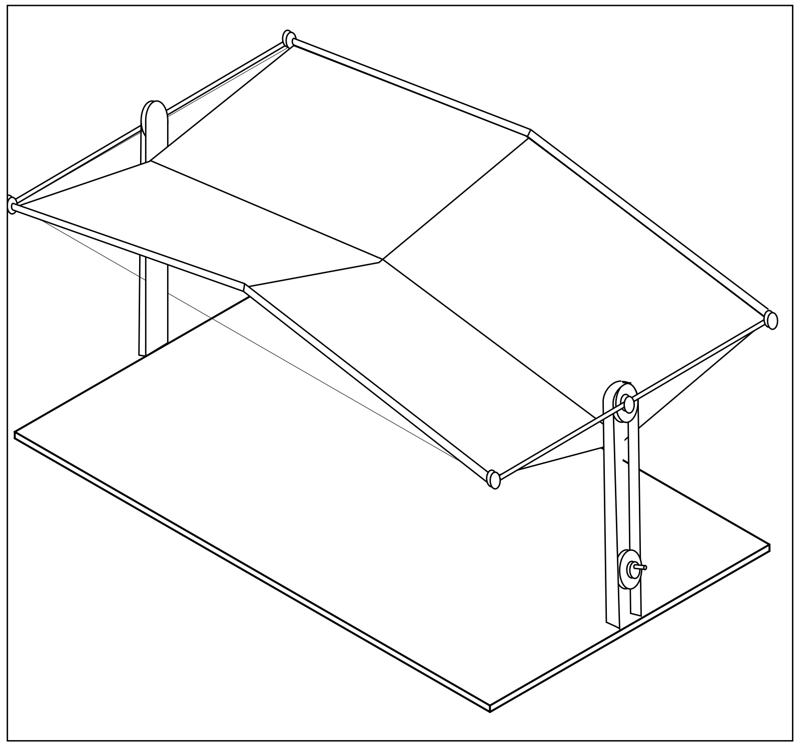
From the existing solutions, the gap in the market identified is for a small scale retractable canopy for public space. The existing solutions are either stationary, large scale or only operated by owners of the canopy. The intent of this project is to make public space more accessible so all members of the public must be able to operate it.

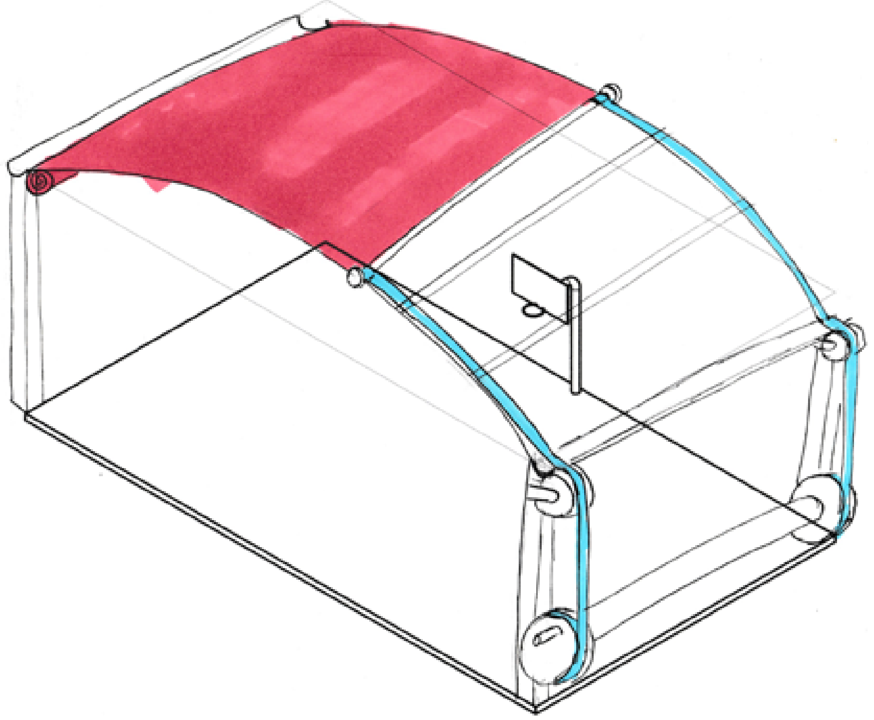
user requirements

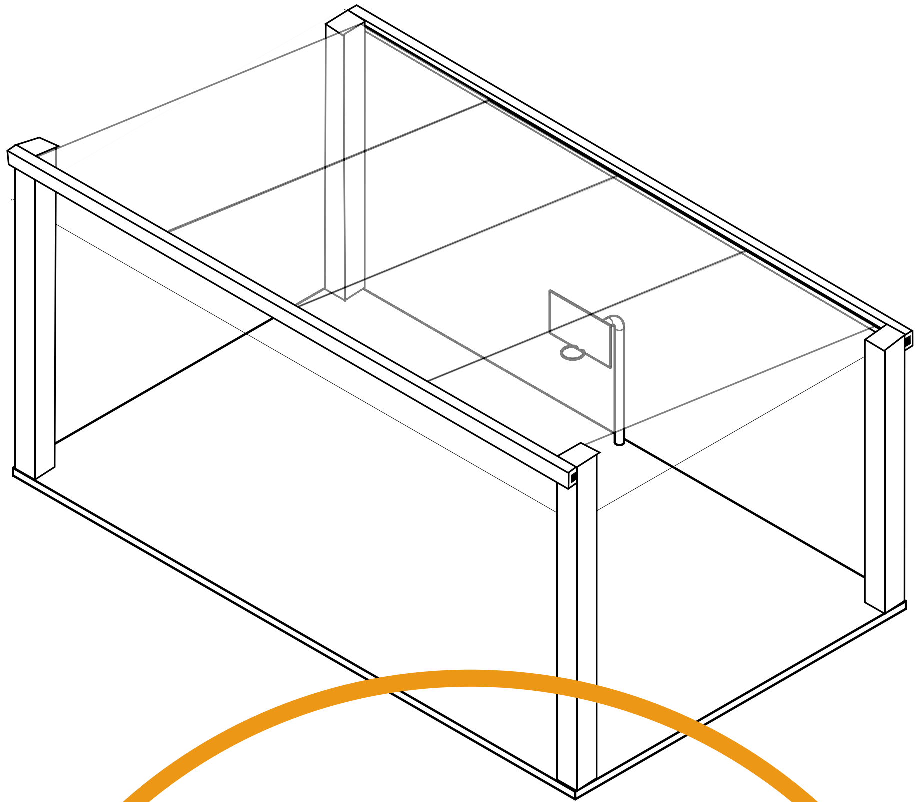
- safe to operate
- works reliably
- inclusive user interaction
- must provide shelter from the rain
- must be able to retract to allow users to play in the sun

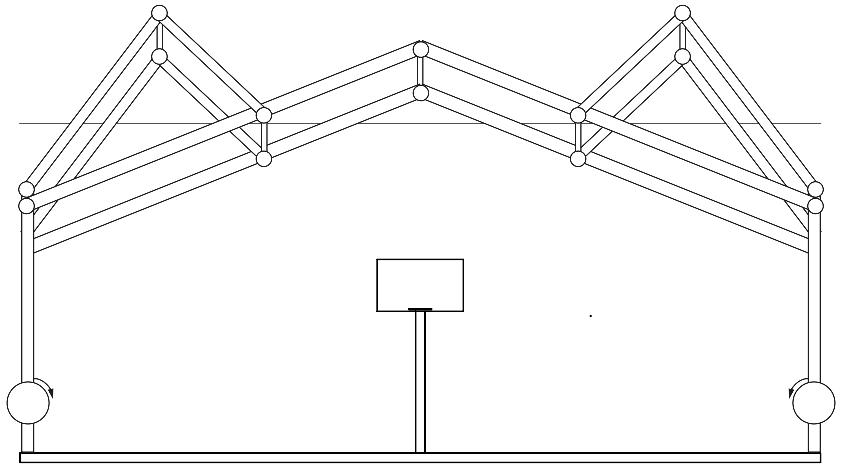
technical requirements

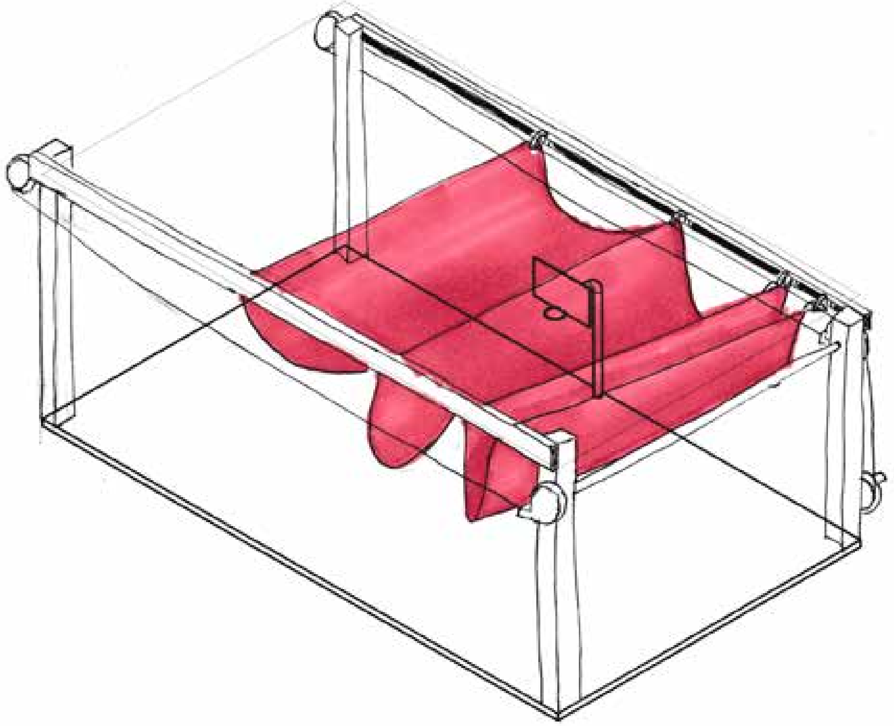
- must cover a basketball half court to facilitate 3v3 street ball
- must be high enough to not interfere with long range shots
- low user input force so no one is deterred from using it

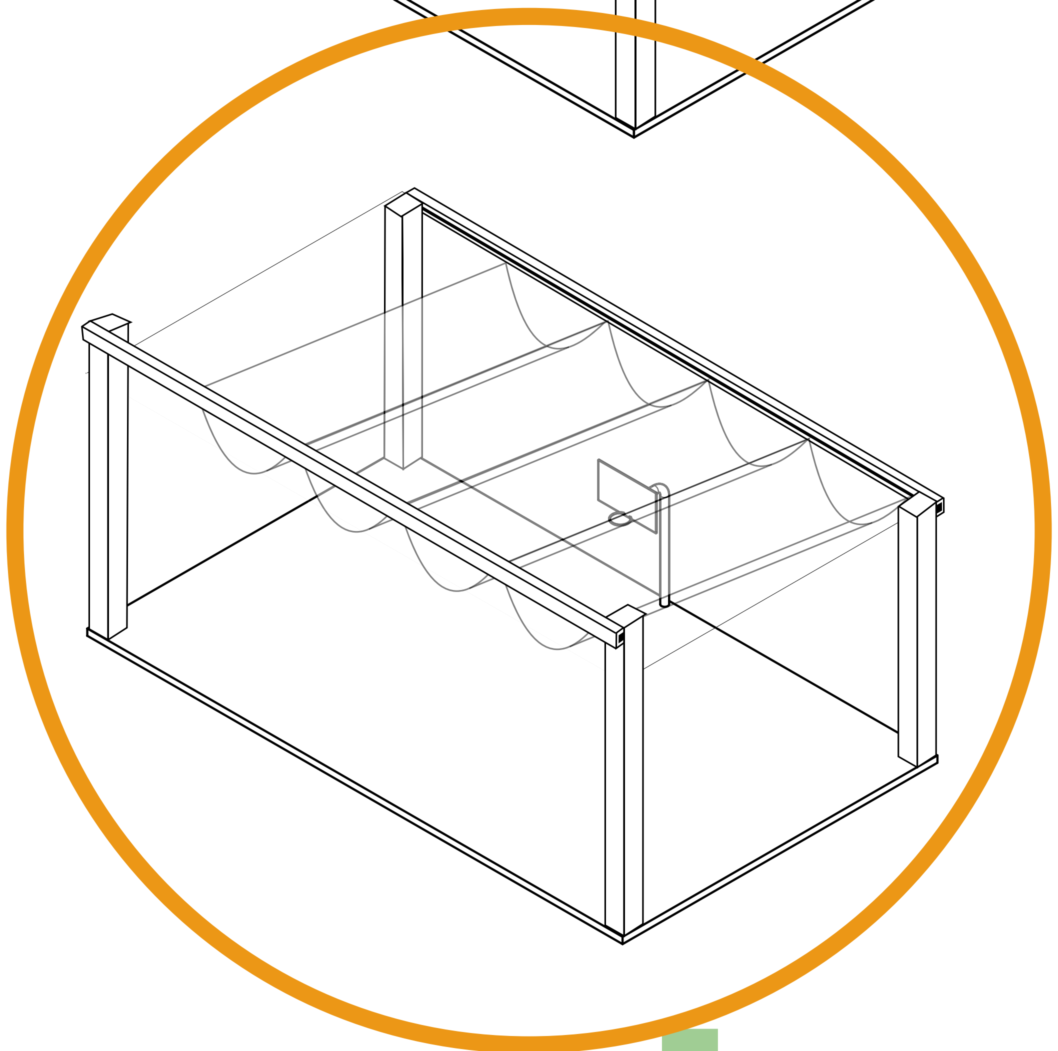


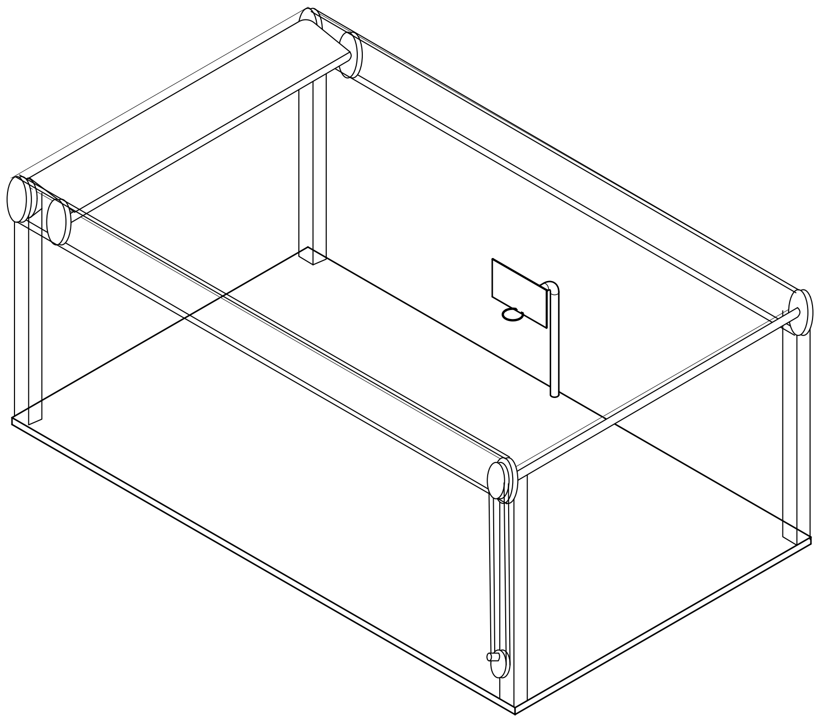












concepts

Scenario

The default position of the canopy is deployed, to prevent rain from falling on the court when it isn't occupied. However, the users can retract the canopy whenever they feel the weather is suitable for basketball. Based on the user interviews this is likely to be sunny days.

interaction 1

To retract the canopy, the user must first disengage the lock by pressing the middle button which pops out from the locked position.

interaction 2

The user then retracts the canopy by turning the wheel anticlockwise, the user can see the canopy retracting and can use this visual cue to tell when to stop.

retraction

Scenario

If weather becomes unsuitable for outdoor basketball the user can deploy the canopy to shelter the court. Alternatively the user might also deploy the canopy when they're finished to prevent the court from getting wet in their absence.

interaction 1

The user turns the wheel anticlockwise to deploy the canopy until it feels too tight to turn

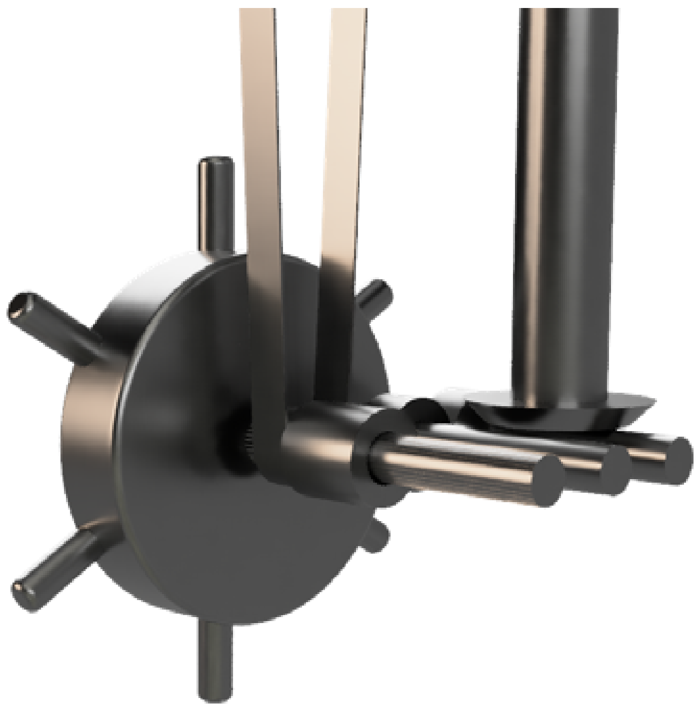
interaction 2

The user then engages the second gear ratio by pressing in the button in the centre which latches itself.

The user can then continue to turn using the same force to tension the canopy

Again visual indicators tell the user when to stop as the membrane will have reached the end.

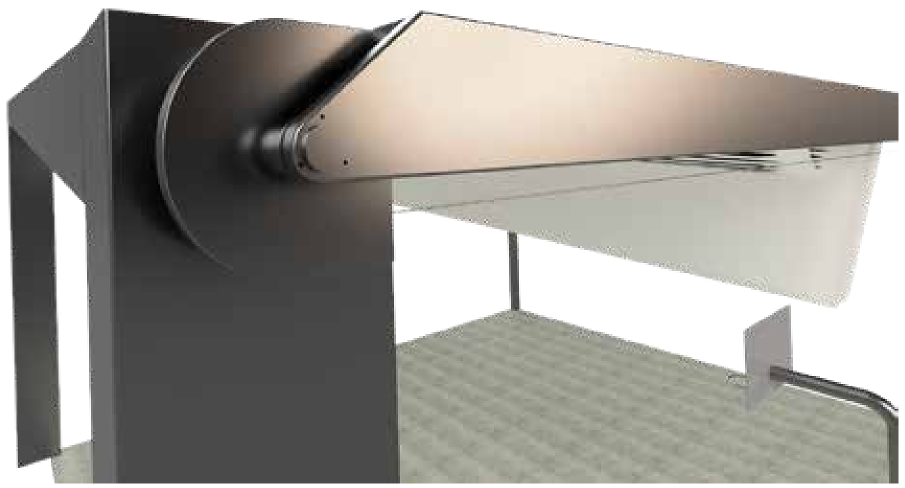
deploymemt



stage 1
User turns the wheel which drives a system of gears

stage 2
Gears turn an angled shaft which drives the two coils on either side of the structure

stage 3
The shaft transfers the rotation to both sides of the canopy for even deployment



stage 4
The coil winds up a wire which pulls the rollers to create retraction or deployment

manual drive
The decision was made to have the user manually operate the system rather than rely on motors or electronics. This was for maintenance purposes as canopy is to be positioned to operate in the public realm. This eliminates the need for an external power supply and means the system can be more robust.

cable traction
Cable traction was the driving method chosen as this system is simple, robust and reliable. This method uses wheels along a track that are pulled by cables which can be manually driven. It is one of the most common retraction methods meaning it is reliable, it can be manually driven which makes it suitable for outdoor public space.

tensile membrane
A foldable membrane structure was chosen as it is the most suitable for smaller scale applications because it occupies the smallest amount of space when retracted. Membrane structures also require far less foundation as they are lighter, this is suitable as the retractable canopy is not mounted to a building.

A foldable membrane structure was chosen for its suitability in smaller scale applications. In a public space project this is important to minimise build costs and limit changes to the surrounding infrastructure. Another benefit is that light weight structures require less supporting foundation.

how it works

materials

membrane material

tenara

Tenara fabric is a form of ePTFE that has been specifically engineered for foldable tensile membrane structures.

specifications

- tensile strength - 4000N/5cm
- thickness - 0.5mm
- weight - 1080 gsm
- translucency 40%

selection process

membrane requirements

- suitable for folding applications
- suitable lifespan > 15 years
- suitable price range
- translucent
- good tensile strength

research

I consulted research papers detailing common fabrics used in tensile membrane structures and eliminated the ones that could not be used in folding applications.
The search was narrowed to PVC coated fabric, ETFE, Dyneema and ePTFE. the latter was the best suited out of this list as it has a long lifespan, good mechanical and optical properties and has been tried and tested in similar industry applications.

granta edupack

This decision was validated using material selection software Granta Edupack. The results showed PTFE as the most suitable material when its tensile strength was plotted against the Young's modulus.

structure material

press hardening steel

The structure will be made out of steel. Press hardening was chosen for its price, stiffness, and processing properties. It is able to be welded and cold formed into rectangle hollow sections which the structure will be made from.

specifications

- Young's modulus - 221GPa
- Yield strength - 990MPa
- Price - 0.637 GBP/kg

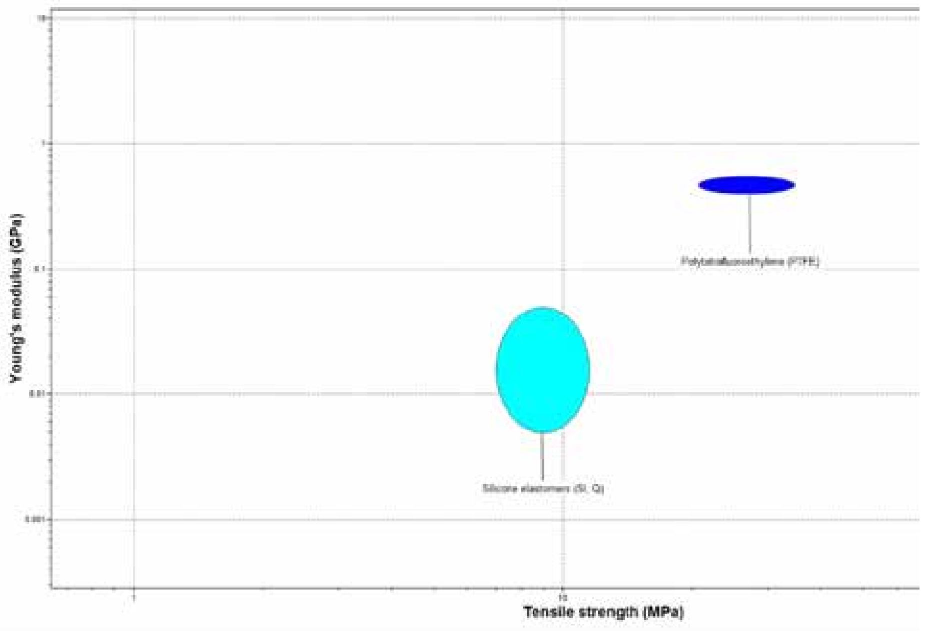
selection process

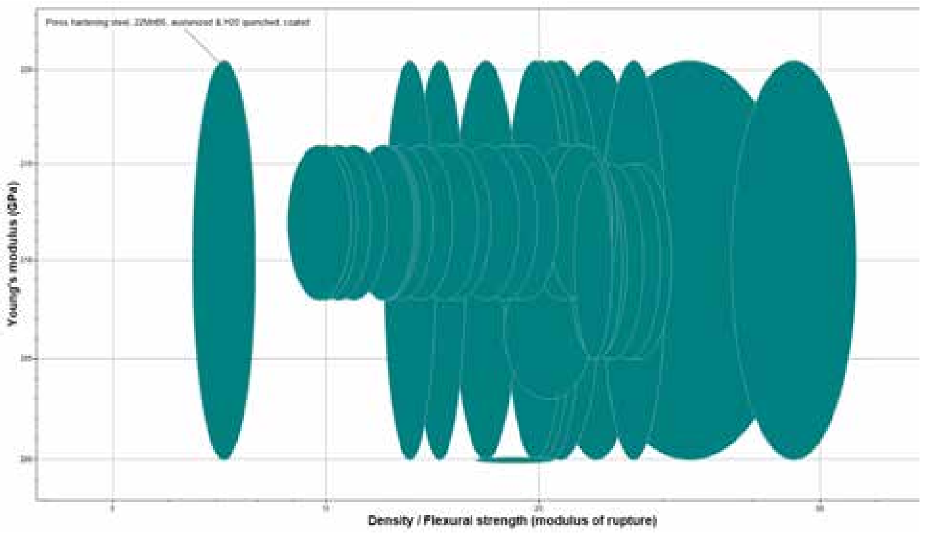
structure requirements

The supporting structure material must be strong enough to support the tension in the membrane. Beam bending calculations were conducted to find the minimum second moment of inertia needed to support the canopy.

granta edupack

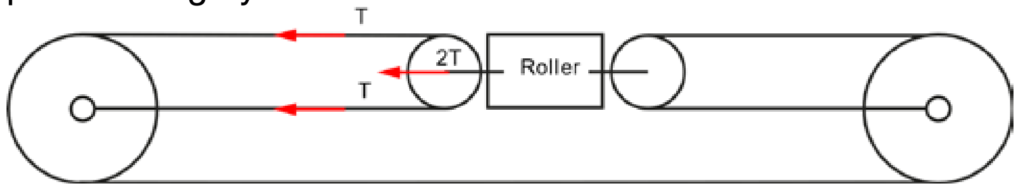
Material selection software was used to determine the best material for the structure. Calculations determined that the structure is weakest in bending so a plot of Density/Flexural strength vs. Young's modulus would give us the material that is lightweight, stiff and good in bending.





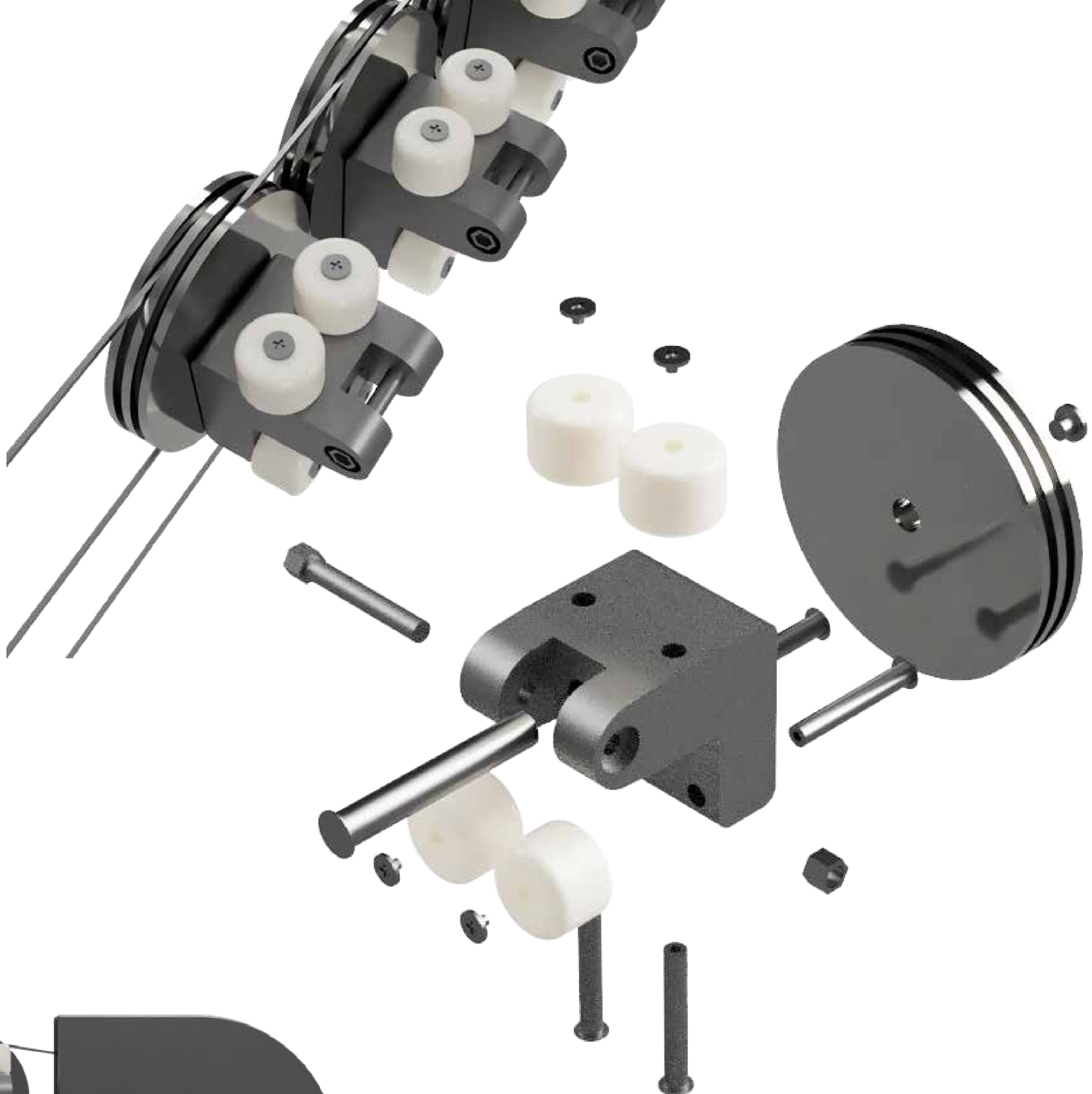
design requirements
The rollers were a key custom part of the project. They must be able to withstand the forces in two directions from the tensioned membrane and they must be able to be driven in two directions to afford retraction and deployment.

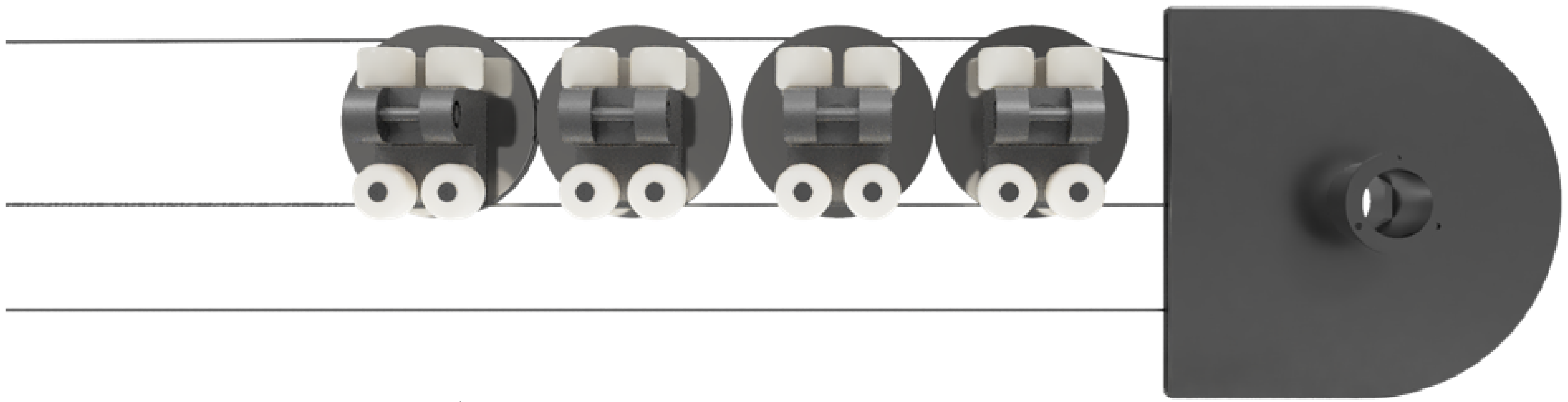
system
The last roller in the train is the only one that is directly driven by the cables. Each cable occupies a groove in the double pulley and is pinned at opposite ends to provide mechanical advantage. The other rollers are pulled along by the first.



nylon wheels
The wheels chosen are nylon load bearing rollers which were picked for the low coefficient of rolling friction between nylon and steel.

hex bolt
The membrane is attached to a hex bolt. This allows for the membrane to be replaced at the end of its life while still being held securely. Finite element analysis was carried out on this part to ensure it would not yield.





rollers

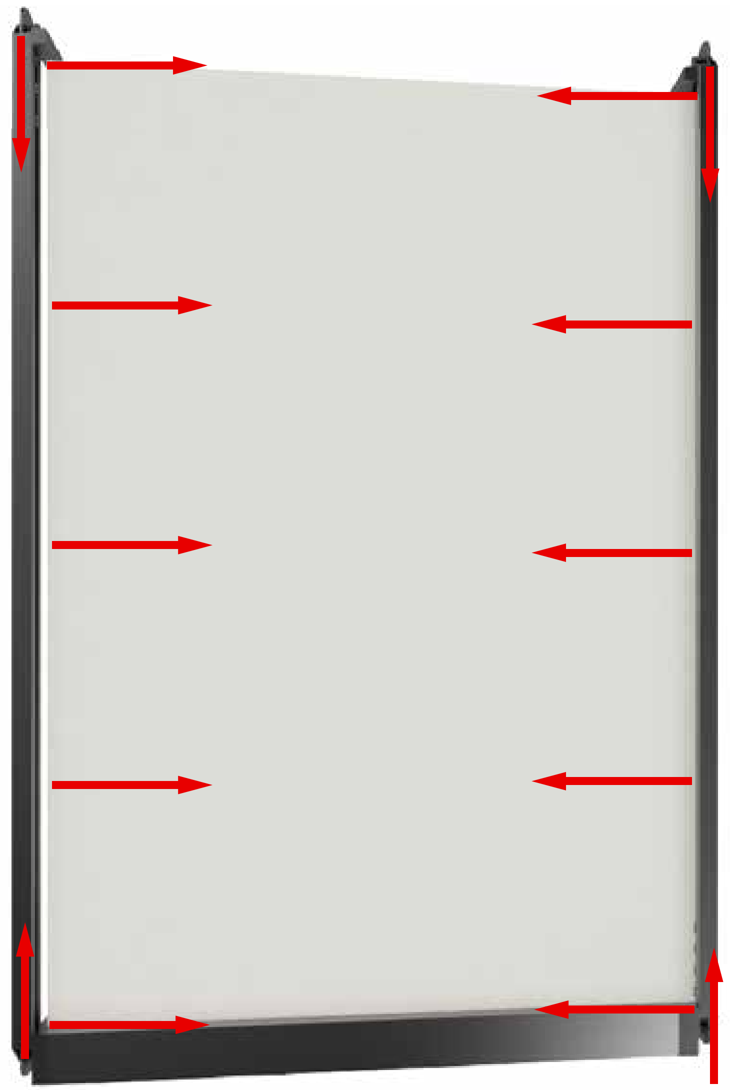
loading diagrams

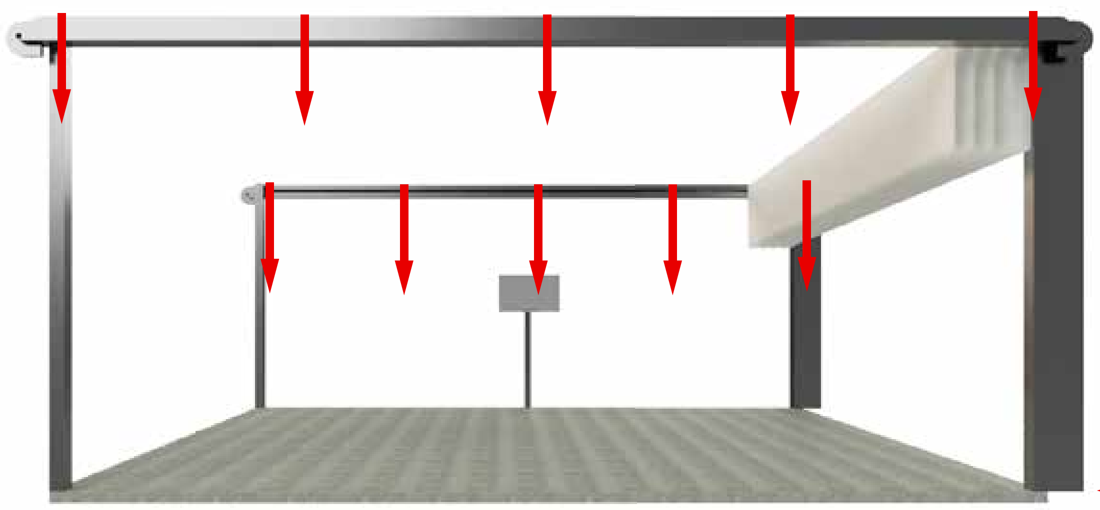
beams

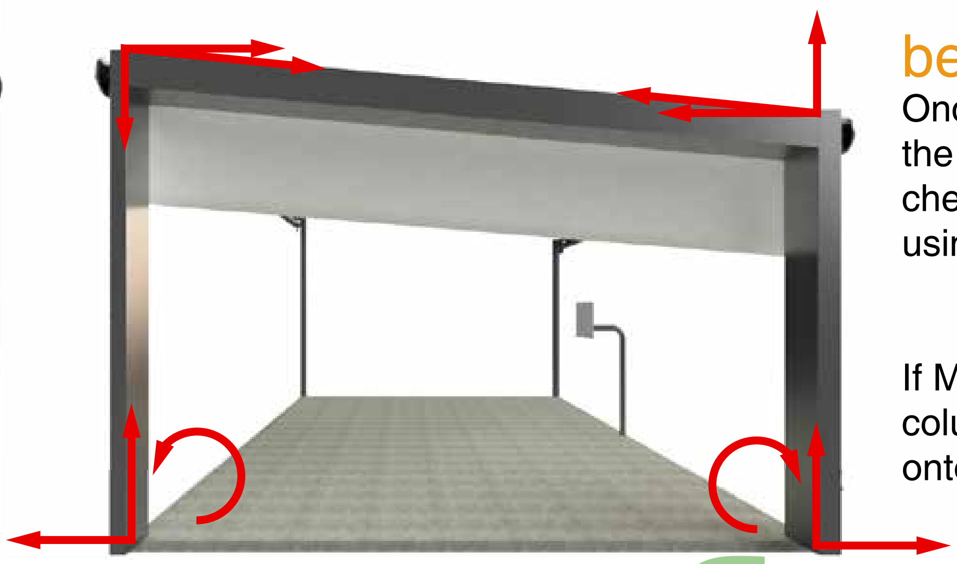
The tension in the membrane creates a constant force in the x and z directions on the beams. This tension force equates to 5 equal forces at equally spaced points applied to the beam by the rollers. There is also a compressive force in the y direction. The beams are subject to bending, deflection and buckling.

columns

The columns act as simple supports for the beams, therefore they provide a reaction force in the x and z directions. These forces, along with the self weight of the columns enact a force on the ground which provides reaction forces. The columns are subject to bending, buckling and deflection.







calculations

deflection and buckling

The formula for deflection is:

$$\delta_{max} = \frac{5wL^4}{384EI}$$

The formula for buckling is:

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

The maximum allowable deflection of a beam is its length divided by 250. Substituting the maximum deflection and adding a standard safety factor of 1.35 onto the load, the minimum second moment of inertia can be calculated.

The maximum compressive load can be determined from the loading diagrams. A safety factor of 1.35 is added in accordance with the Eurocodes and the minimum second moment of inertia can be calculated.

The dimensions of the beams and columns can then be determined from the second moment of inertia.

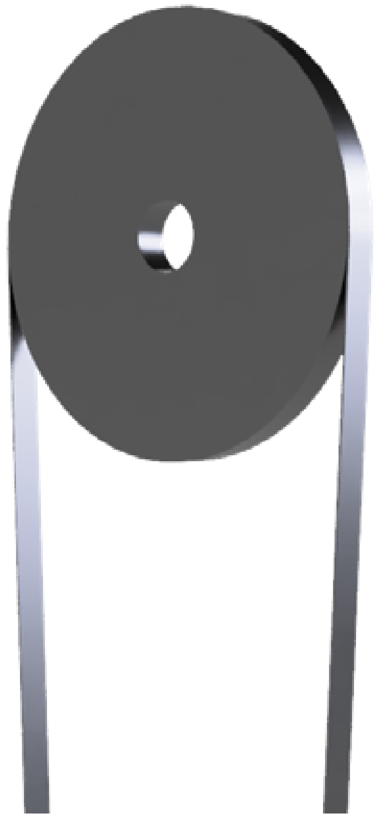
bending

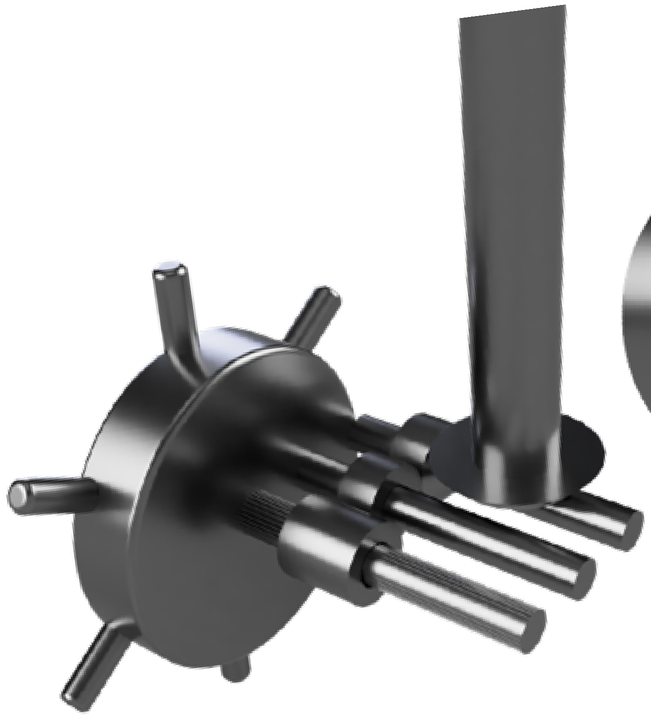
Once the dimensions have been determined to satisfy the deflection and buckling constraints they can be checked to see if they will yield under bending stress using:

$$\sigma_y \geq \frac{My}{I}$$

If My/I is less than the yield stress then the beam or column will not fail. A safety factor of 1.35 was added onto the bending moment.

forces





Gear ratio 1

Input

The user provides an input force of 100N on a 0.3m radius wheel. This produces a torque of 30Nm. This torque is transferred via the axle to a spur gear of radius 0.04m which gives this gear a tangential force of 750N.

Output

This 750N tangential force is chain driven to the top of the structure to a gear of radius 0.31m, this gives it a torque of 232.5Nm. The 0.31m radius gear drives a shaft whuch connects to the coil. The coil has a radius 0.165m, giving the coil a final tangential force of 1.4kN, which is sufficient to deploy the canopy.

Gear ratio 2

Input

The user presses the central axle inwards to engage the second gear system.
The same input force is used but his time a gear of radius 0.1m is engaged, created a tangential force of 300N. This gear connects to a train consisting of a spur gear and a bevel gear. Therefore, the bevel gear has a tangential force of 300N. This connects to a second bevel gear of radius 0.2m at a 90° angle.

Output

The second bevel gear is connected to a shaft with a worm screw at the top. This shaft carries a torque of 60N. This is transferred to the worm wheel in a ratio of 1:120, giving the worm wheel a torque of 7200Nm. The worm wheel drives the shaft connected to the coil, giving the coil a tangential winding force of 43.6kN which can tension the membrane. The worm screw is self locking which allows for safe deployment.

Testing

A test rig was constructed in order to test how big the radius of the input wheel needed to be in order for all users to comfortably provide a 30Nm torque.

The ideal wheel radius was found to be 0.3m as this balanced a manageable input force with ergonomic usage.

As well as the wheel radius, the height of the axle was also tested and it was found that 1.15m from the ground suited most user heights comfortably.

A crank handle input was also tested and found to be a less inclusive input method as users needed a greater range of motion to operate the handle at a 0.3m radius.

gears