Proteus Roofbox

More than just a roof-box - 10 Page Summary - Jamie Macleod

THE GLASGOW SCHOOL OF ART

University of Glasgow

VIA VERITAS VITA

ROOF BOX

FLAT-PACK TABLE

HOME STORAGE

PICNIC SET

Research and identification

Purpose of a roof box

A roof box is designed to expand the storage capacity of a vehicle

The Problem

The design of roof boxes has not changed since the 1960s. They are large, unergonomic objects that need a refresh. Roof boxes are difficult to install, and due to size, difficult to store. For the majority of it's life cycle, when not in use, the roof box lacks purpose and occupies space. After critical and extensive research into the life cycle of the product, I found that only two possibilities exist. The roof box stays in storage and is placed on a vehicle when required. The roof box stays on the car continually, even when not needed.

Roof box Requirement Criteria

It is essential that any roof box meets the following criteria:

- Sufficient storage capacity (two golf bags)
- Waterproof
- Aerodynamic
- Ability to attach securely to roof bars
- Ability to be fitted to any crossbar spread
- Lockable
- Lightweight
- Accessible opening system

Identified issues

- Large and bulky
- Occupies valuable space when not in use
- Lacks multi-functionality
- Lack of ergonomic carrying and installation handles
- Inaccessible and inefficient opening system
- Roof box installation a challenge due to size and shape
- Lack of user customisation available

Two potential solutions

Two solutions to the problems were identified. Firstly, a resolution that aimed to reduce the storage footprint of the roof-box. Secondly, and most imperatively, a solution to enhance the multi-functionality of the roof box.

Market Research

Market research highlighted a large and heavily saturated market. Despite an abundance of available products and manufacturers, roof box design stays constant throughout the market. No manufacturers are willing to stray from the idea that a roof box is more than a simple storage box.

Conventional roof boxes

The conventional storage roof box consists of a plastic or fibreglass top section attached to a more rigid base section. Typically manufactured via the vacuum forming process.

Roof bags

There are many different roof-bag products on the market. However, all were deemed poor options due to undesirable attachment straight to the vehicle roof, alongside insufficient security features.

Product cost

Prices varied substantially throughout the market ranging from £150-£1500. This price variation is down to both quality and the brand of manufacture. Market research revealed the observation that one gets what one pays for within the industry.

User Research

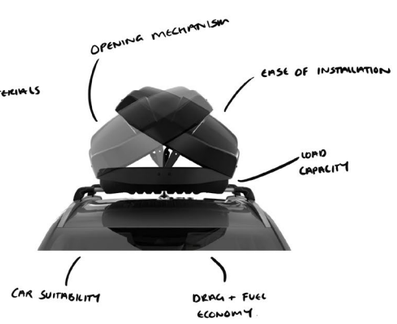
Extensive user research was carried out both with a physical user group and an extended network. I centralised research and user testing around the analysis of the user experience. This identified problems with current roof-box design.

"Not used frequently" - A questionnaire answered by over 40 contributors highlighted that users rarely use their roof-box more than six times per calendar year.

"Takes up too much space" - because it is such a large object that lies dormant people find it difficult to store. Occasionally this can result in a roof-box being sold or given away due to a lack of space. It also contributes to the number of potential customers who don't own a roof box as they do not have free storage space.

"I can't install it on my own" - Many people struggle with lifting the roof box onto a car. This is down to two reasons. Firstly the size and weight. Secondly, the lack of handles incorporated in the design to help with the process. This was tested and analysed extensively with my close user group

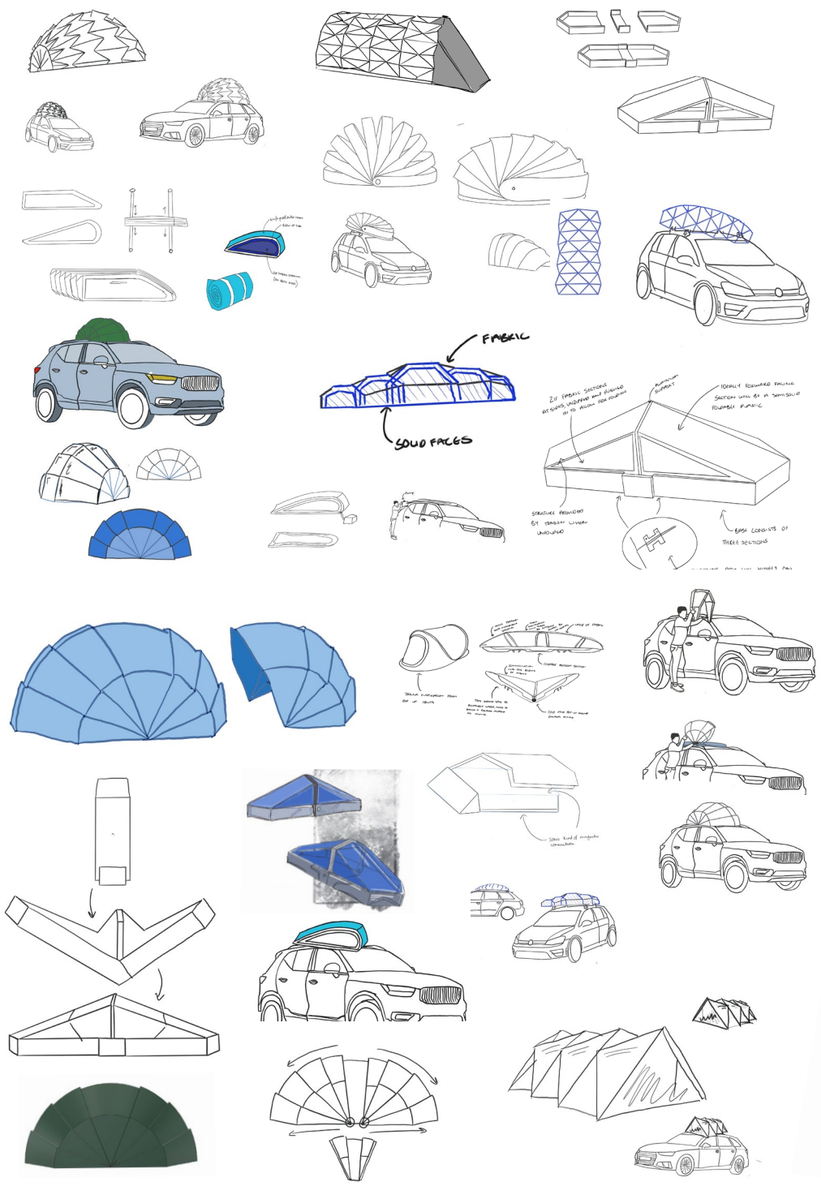
"It's ugly to keep in the house" - Roof boxes are designed to be aerodynamic and adhere to vehicle aesthetics. However, this leaves them out of place and an eyesore in a housing environment.



Concept Generation - Stage 1

Exploration of initial solution

Discussions with users revealed that reducing footprint and volume would provide a solution to storage issues. This prospect was explored in detail, allowing for the generation of multiple concepts. Discussions revealed that a smaller, compact design would allow for a more accessible, efficient and not to mention safer user installation process. This theory was tested using a dumbbell that simulated a structure with less distributed weight.

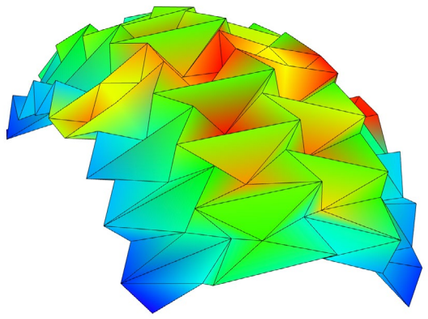


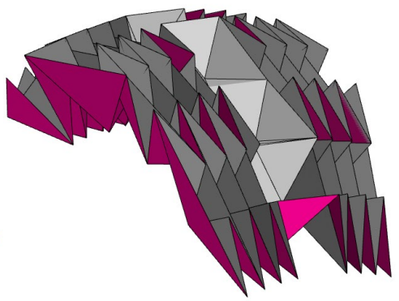
Concept Requirements

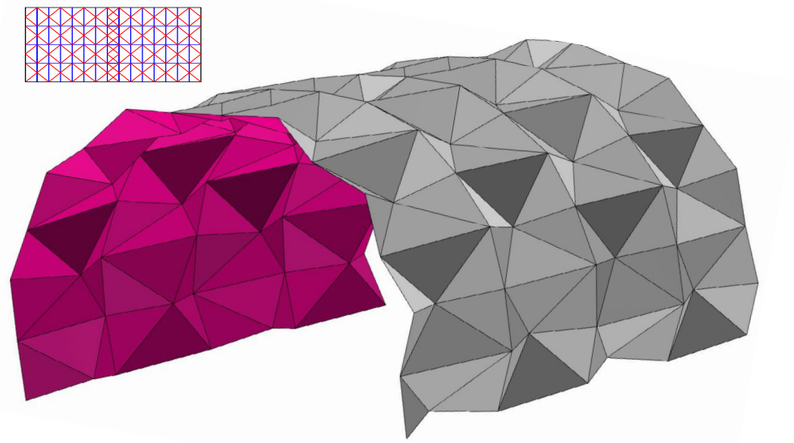
Whilst developing concepts the following requirements were detailed
- Meet all of the detailed Roof box requirement criteria
- Be fold up/small when not in activation
- Light enough for installation
- Strong and secure material
- Waterproof

Origami

Origami, and the art of paper folding was an interest from the offset of the project. I hypothesised that an origami structure could create an expanding system perfect for storing as a flat-pack product. In combination with exploring forms from paper, an incredible piece of software was used to simulate my designs. Origami simulator allowed me to input flat design sheets and have all of the folds manufactured to a specified angle. The software was complex and required multiple iterations. The folding and unfolding of each design was simulated, displaying the full potential of origami. The outcome of my origami development is shown below. It could have real potential in shelter design.

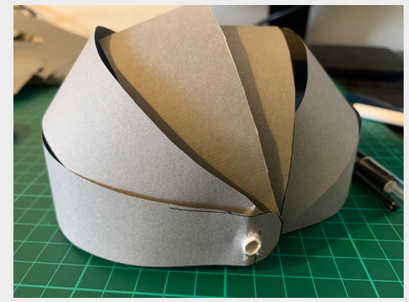






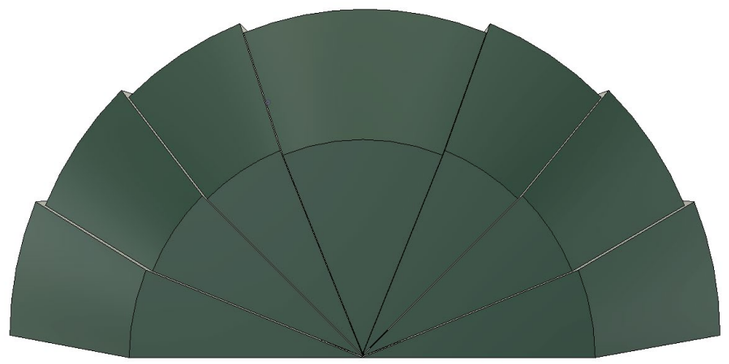
Biomimicry - Armadillo structure

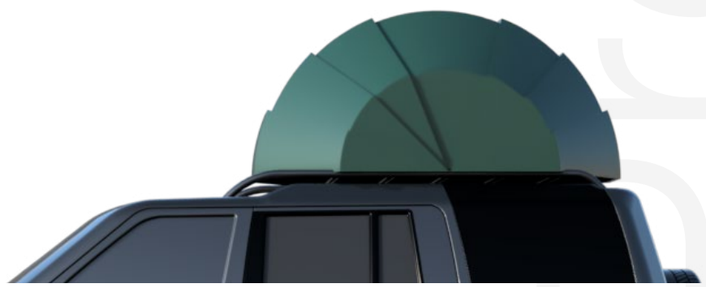
Interest in biomimicry and architecture led me to a focus on the potential of a natural armadillo structure. This structure was envisioned in a fold-up template perfect for both storage and installation of a roof box. A hinge system was designed and prototyped that would allow for the expansion of the product from a central point. This concept was presented in the interim review.



Conclusion

Origami was discontinued as opening the product would ruin the structural integrity of the roof box. The armadillo structure was deemed ungainly and too bulky when folded.





“A roof box with a function off the car and will never need to be stored”

Conclusion of stage 1

Ultimately having reconsidered the user findings, I decided that reducing the storage footprint was not the best solution. Practically it was not sufficient in meeting roof box criteria. Regarding the market, it would have carried out a similar function to roof bags that were already available. A re-evaluation of the project was inevitable.

New Direction - Solution 2

After much deliberation, a second direction was established. By focusing on the areas where a roof box exists and the natural attributes of the shape, concepts were developed aimed at enhancing the multi-functionality of the roof box.

Finalised concept and brief

Re-imagine the roof box to design a product that exploits all areas of its product cycle. It must give the user a function.

- At home
- On the car
- At the destination

Concept evaluation

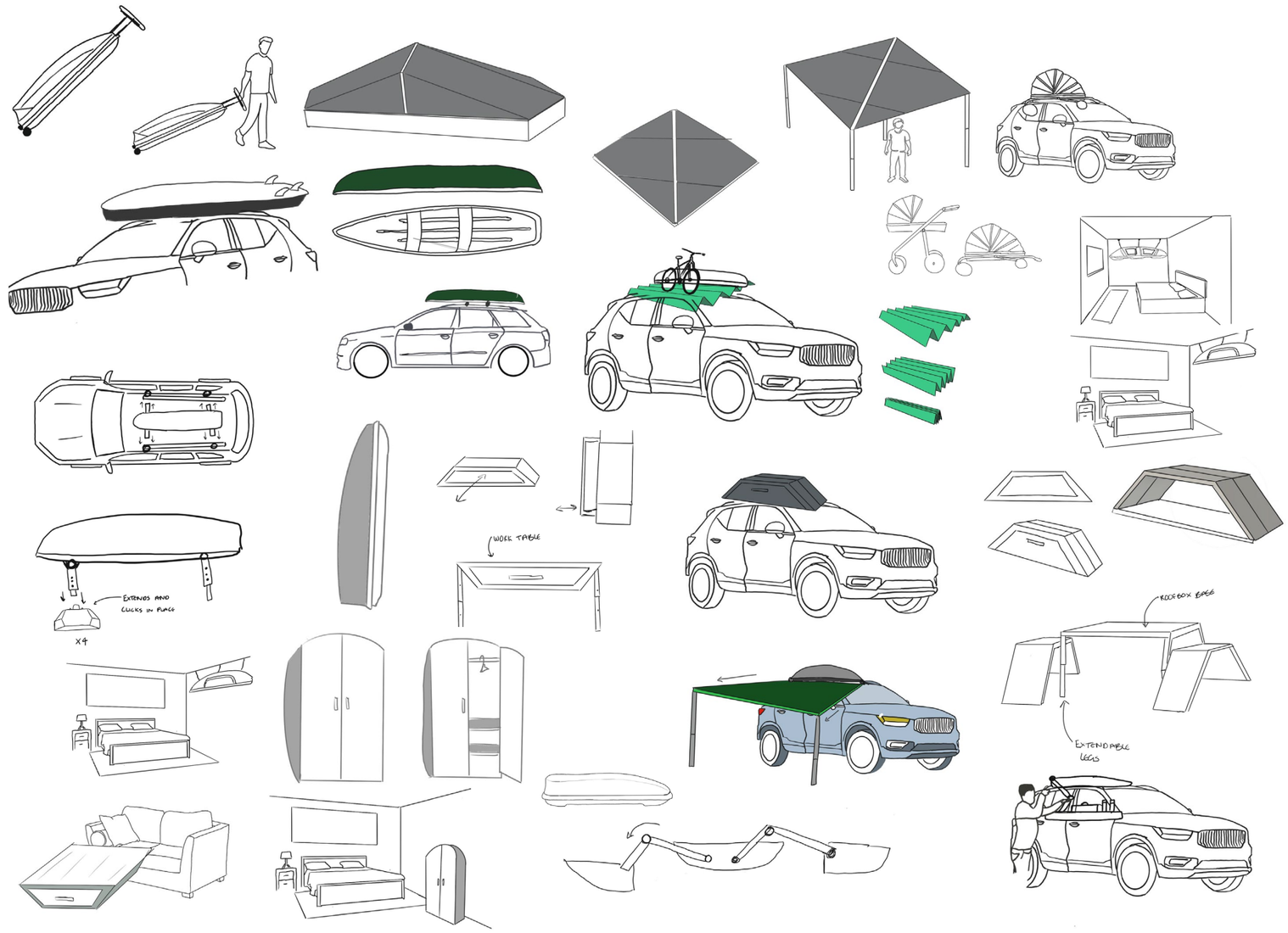
Concept evaluation primarily revolved around the user group and user group communication. People were asked to choose which concept they felt was most effective. This data was collected, and the outcome processed. Furthermore, concepts were reflected on individually.

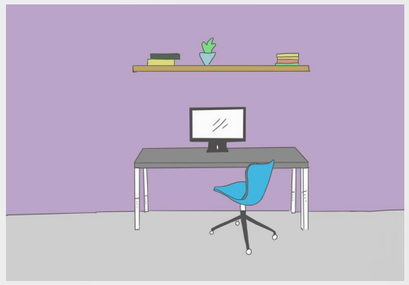
Chosen concept

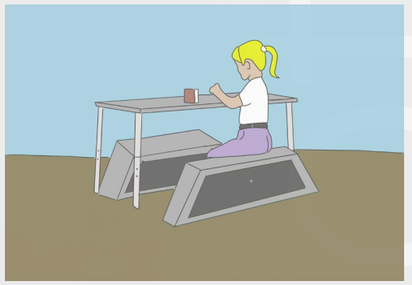
The product is the re-imagination of a conventional roof-box into a multi-purpose object. The design is a roof-box that has function both in the home and at the final destination.

The product is split into three sections. A base and two container sections. It will provide the following functions.
- Roof box
- Home storage
- Flatpack table
- Picnic set

Concept generation - Stage 2







Multi-functional roof-box development

Prototyping and user testing

Numerous prototypes were created at a small scale however, the ultimate test would involve users interacting with a full-scale prototype themselves. Local removal company Clockwork were very generous in providing me with adequately sized cardboard. This allowed for a simple prototype to be created.

Feedback

The reception and feedback on the prototype was very positive. Dimensionally the box fitted both indoor and vehicle environments. The process of installation was also noted to be substantially easier. The splitting of the roof box into three defined sections has resulted in a product with much more manageable parts for transportation and lifting. Even though this was an early prototype, users provided positive feedback on the aesthetic of the product. However, there were some critiques regarding the boxy shape of the product when mounted on the vehicle. There was a real sense of optimism from user engagement.

Opening mechanism

A simulation of the loading and unloading procedure was created using a box. User feedback highlighted that the roof box drawers should open upwards. It was also established that the hinges must be able to hold the weight of the drawer to allow the user to load and unload contents safely with both hands.

Developing installation procedure

Connecting each container to the base whilst on the car roof was identified as one of the most important product features. To create the optimum user process, the product was to be assembled on the top of the car to allow for the easier lifting of each section individually. Many systems were researched and considered. It was clear from the offset it was going to need to one of the following two options.

1. Lifted and placed in position
2. Slotted and slid into position

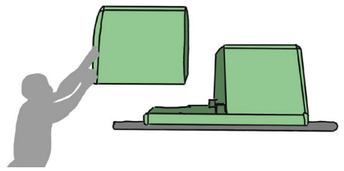
Through user testing, I concluded that a combination of the two would be most effective. The container will be lifted and placed onto the base surface, where it can then be adjusted, lined up and slotted into position when not bearing the full weight of the section. This system was tested using both cardboard and 3D printing.

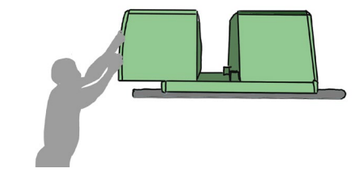
Material testing and selection

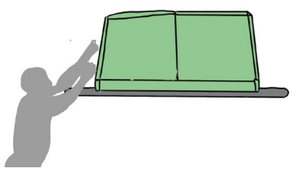
Samples were collected from a number of different providers. Due to its good mechanical properties, ease of manufacture and colour selection, ABS was chosen to form the base and container

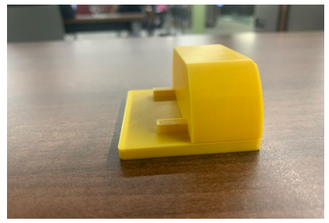
Handle positioning

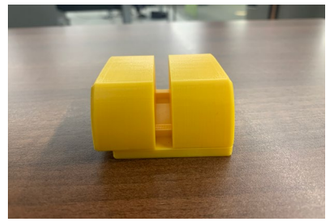
Testing allowed for the optimum position of handles to be established. Handles will be included in the design for both carrying and installing the product. I concluded the dimensions of these handles through further user testing

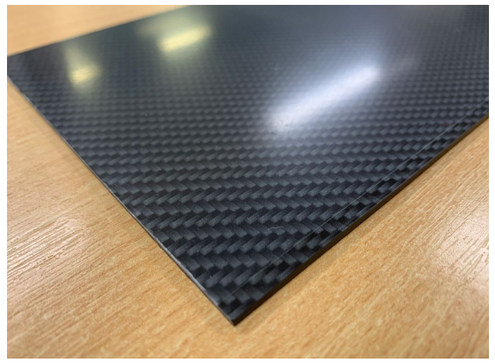




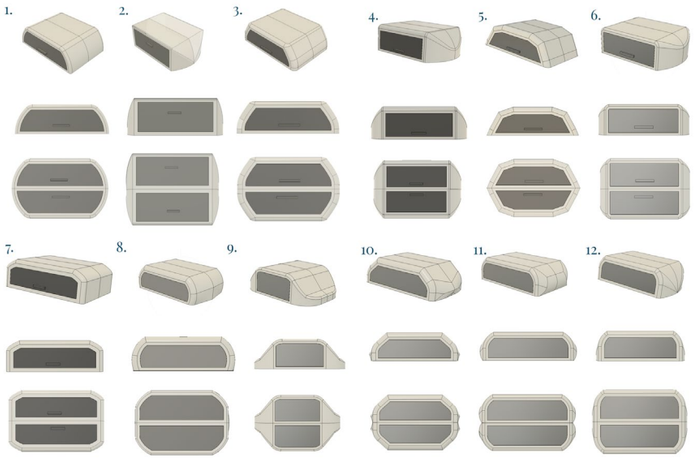


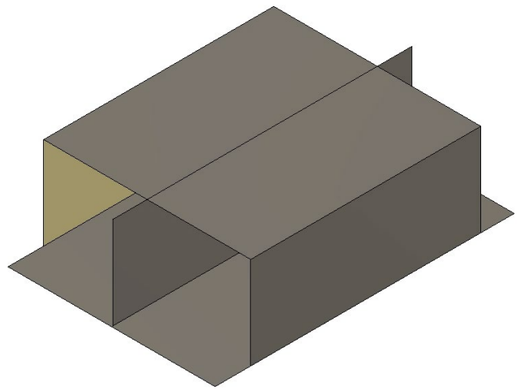


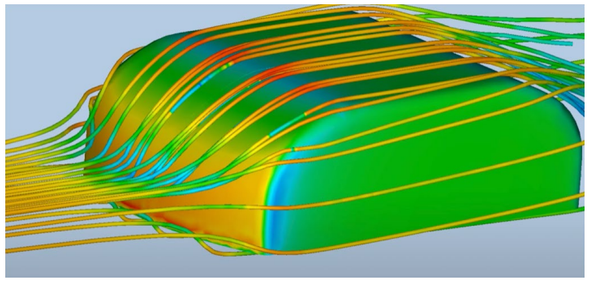


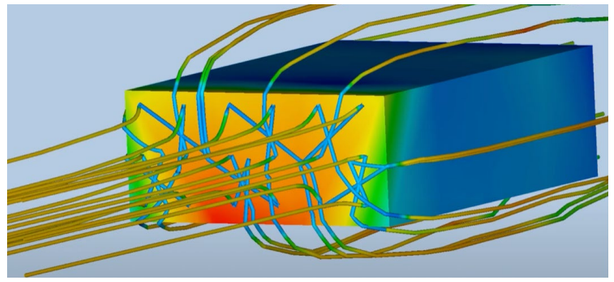


CFD shape development









Aesthetic requirements

Due to the products multi-functionality there are different environments in which the design needs to meet aesthetic requirements. The design of a roof box and a piece of furniture have conflicting objectives. As a piece of furniture, a boxy shape is desired; however, to look and perform aerodynamically on the car, the body requires considered and smooth compound curves. It was concluded that the aerodynamic drag coefficient would be the pivotal factor to select a shape, with optimisation established within shape function limitations.

Shape limitations

When creating of an aerodynamic shape, the limitations of function had to be considered. The container sections require flat surfaces on four sides of the body. These flat surfaces were non-negotiable from a shape development standpoint, resulting in a limited malleable region. The cross-section of the product was also a set parameter.

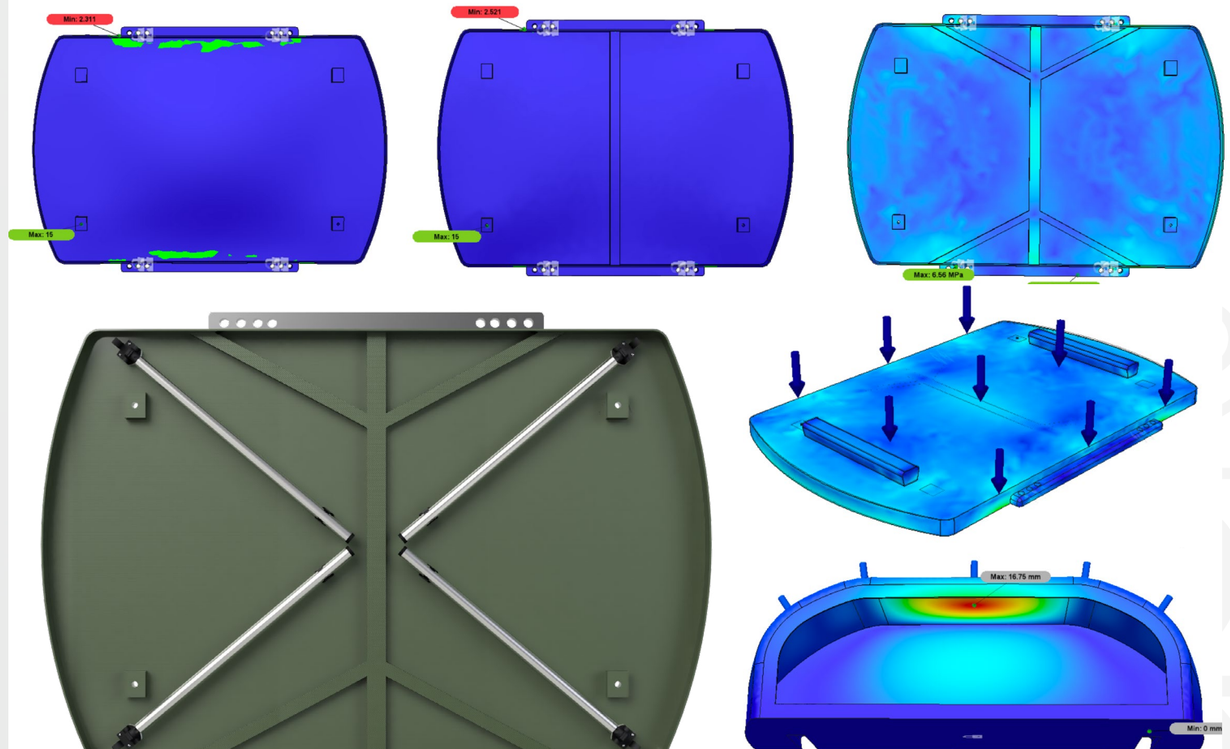
Iterative Process / Testing

Twelve different shapes were developed using multiple CAD modelling techniques. A simulated wind tunnel environment was then created. Each body was put through the simulation, allowing for data collection and calculation of the drag coefficient.

Further optimisation

The shape with the lowest drag coefficient was selected for further development. I added curves from an Alfra Romeo 33 Stradale to improve the form aesthetically. As a result of the optimisation, the drag coefficient was reduced from 1.75 to 0.72.

FEA Structural Development



Car roof loading capacity

The maximum car roof loading capacity rarely exceeds 100kg. Given the 10kg weight of each product component, this leaves a loading capacity recommendation of 70kg.

Structural Analysis of Base

FEA simulation was carried out on Fusion 360. Three simulations of loading were performed on different models of the product base. Each model had an extra level of structural ribbing. The base analysis without any structural support allowed for the development of ribbing in the areas with the highest structural stresses.

With the introduction of the final structural rib layout, the base achieved a safety factor of 3.05 under a load of 800N. This constitutes a maximum load of 2400N (245kg)

Structural Analysis of Container

As the product's function requires the container to act as both a home storage unit and a seat, it is vital that the section does not deform under a person's weight. Structural ribbing was added to the area with maximum displacement. A safety factor of 5 was achieved.

Roof box

Home storage

Table

Picnic set

Final Design

On the Car

The base and two containers combine on the roof of the car to create a product that carries out the function of a roof box. The product can be opened from either side, and each container has the capacity to carry a complete set of golf clubs. A locking mechanism provides security for the user and their belongings.

At Home

The product carries out two functions at home to ensure the multi-functionality of the product throughout its life cycle. The container subsections stack and snap together using magnetic strips to form a home storage unit. The base exploits the natural flat surface of the product to become a flat pack table that can be used when and how the user desires. Both products can be used outside due to their waterproof and weatherproof design.

At the Destination

The entire product combines off the car to create a picnic table. This can be used in any environment and would be particularly useful in camping scenarios. Furthermore, the containers could also be used off the car to store and lock personal belongings in areas such as the beach.

Potential for Modular Development

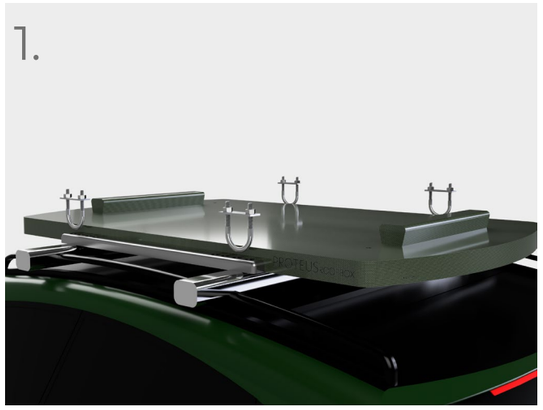
With a roof box design that comes in 3 sections, it has always been a plan for future development to realise the potential of not installing both containers at one time. In this scenario, the other side of the base could be used to attach other items such as bikes or skis.

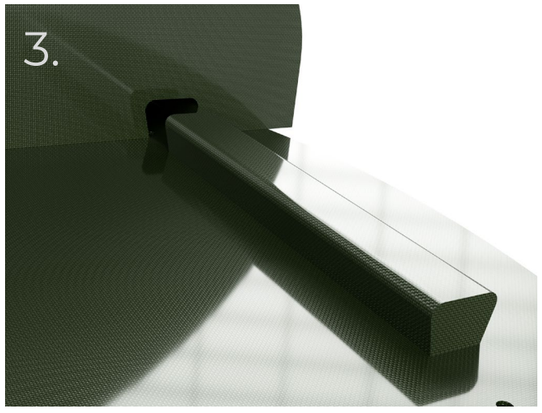
PROTEUS ROOFBOX

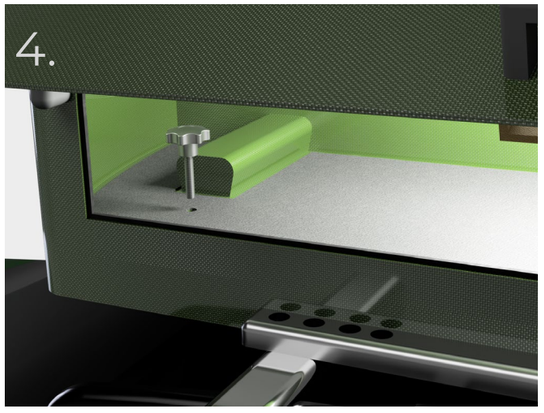
Design Detailing

Installation process

1. The base is first placed and secured on the roof of the vehicle. The base has an adjustable system that allows it to fit on various cross beam spreads. It was decided that the base would be connected using a method already available. (e.g as U-bolts or snap and click.)
2. Each container is placed and lined up with dovetail runners on the surface of the base. The containers are pushed into position.
3. The user inserts four screws through both the container and the base in the corners of the roof box. These inserts are designed in accessible locations

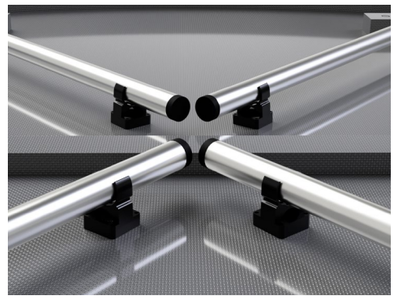


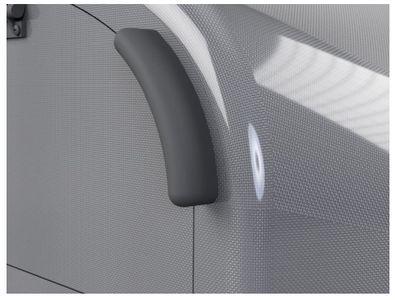


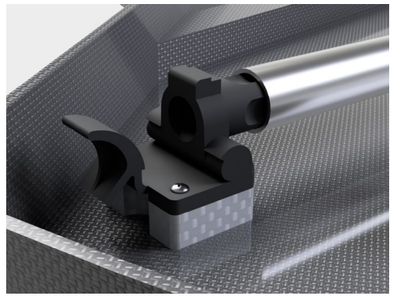


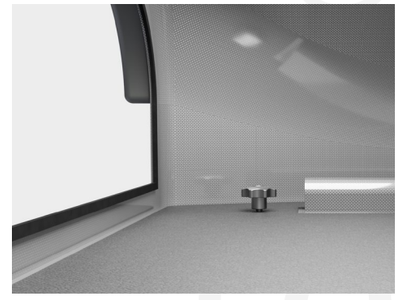
Potential for other attachment

Key Features









Locking mechanism

A roof box must have sufficient security when storing belongings. The Proteus roof box uses a key lock system present on the door of both containers. Research was carried out into other potential systems, but a key lock was ultimately the most intuitive and straightforward option. In future, a wireless system that utilises the central locking of the vehicle could be developed. In future, there is scope for a wireless system which works alongside the central locking of the vehicle.

Ergonomic handles

Both user testing and anthropometric analysis contributed to the development of the handles for the product. Handles have been implemented in positions that benefit the user when installing the Proteus, aiding them when aligning and pushing the containers into place.

Fold-able legs

The length of the legs has been optimised by orientating them centrally into the base. The legs give the table a height of 60cm.

Leg hinge and clip system

The foldable set up is achieved through the use of four nylon hinges. Circular leg hinges have been selected as they are a more aesthetic and practical option. When folded the legs are held in position by clips offset from the centre point of the base. When the legs are unfolded, they are locked in position via a hinge

Waterproofing

A fully weatherproof design must be achieved. ABS has excellent waterproof properties, consequently the opening system was identified as the highest risk of leaking. A rubber gasket seal has been implemented between the door and the container. When the door is closed, the gasket is compressed which creates a seal.

Alcantara lining

Alcantara leather has been implemented on the bottom surface to provide a frictional surface that prevents the loaded content from sliding around. As well as providing a frictional surface, Alcantara is often used within sports and racing cars, applying the material to the roof box enhances the products premium nature.

User cycle and User interaction

Installing the roof-box

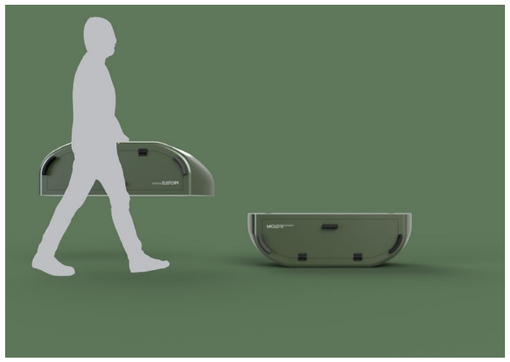
The base if lifted onto the vehicle roof and attached in four locations.

Container one is lifted, placed and then slid onto the dovetail runners until it reaches the desired position.

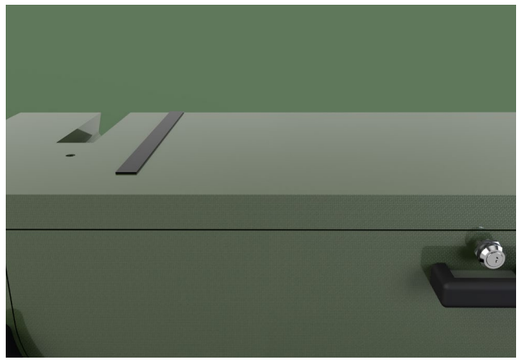
The second container is then lifted and slid into position on the other side of the vehicle.

Fastening screws are screwed in place, two per container. These are strategically placed in accessible locations

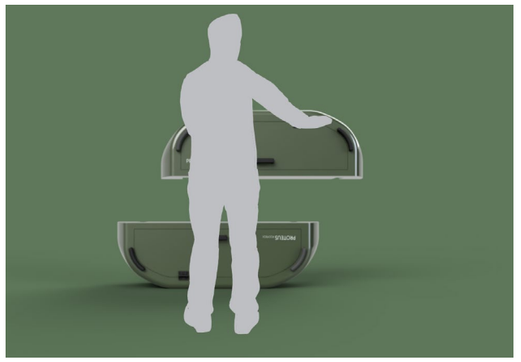
Assembling home storage unit



The first container is placed small end down, exposing the large face upwards.



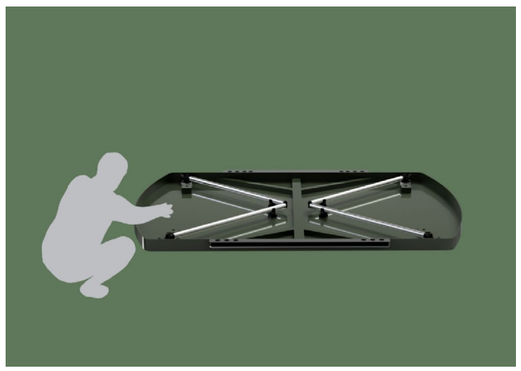
The magnetic strips are identified on both surfaces.



The user lines up the magnetic strips and places the second container down on its matching surface.

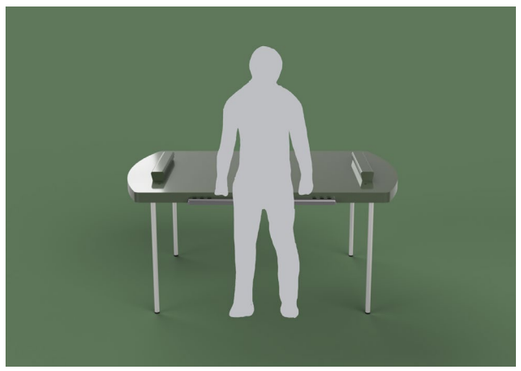
The fastening screws can then be added to provide further stability.

Setting up the fold-up table

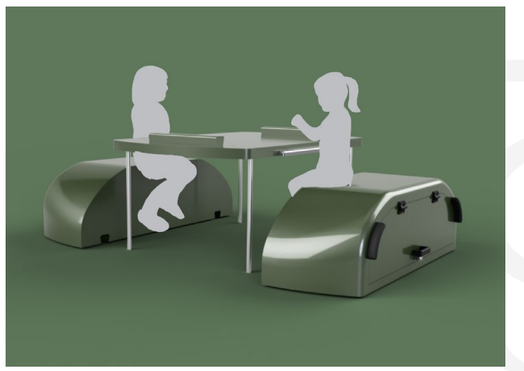


The base is placed surface down, exposing the folding legs.

The user unclips and pulls up each leg individually, Once they reach 90° the hinge clicks, holding them in position

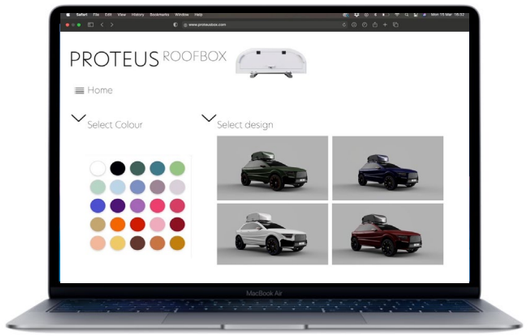


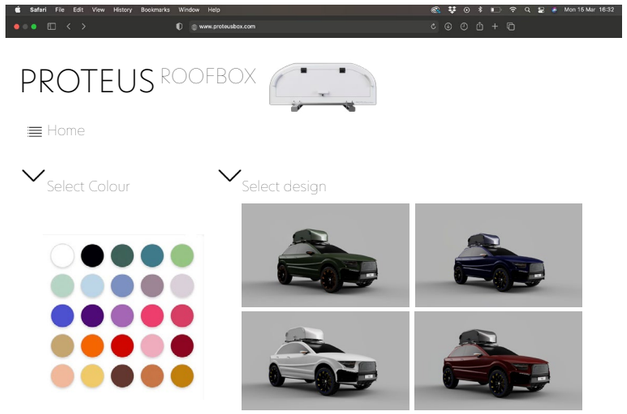
The table is flipped back over onto four legs.

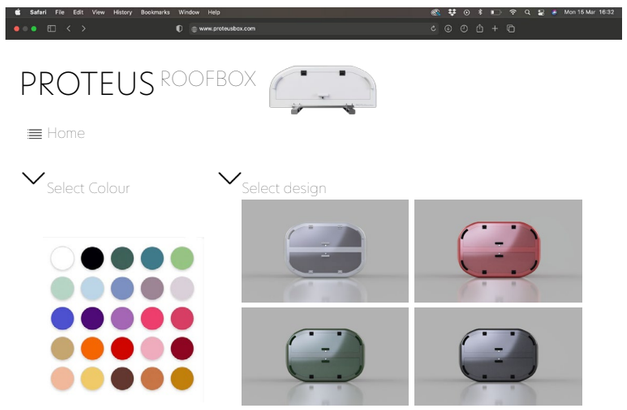


The table can be combined with the containers to create a picnic set.

The Brand and the User







Proteus Roofbox

Choosing a Name

It was essential to come up with a brand name that captures the essence of the product. I researched multi-functional synonyms. Like other key players in the roof box industry, a name with one word is vital in creating a strong and simple brand identity.
The name Proteus, after a god of Greek mythology, was selected.
From its derivation, protean, meaning “versatile”, or “capable of assuming many forms”. “Protean” has positive connotations of flexibility, versatility and adaptability. It encapsulates the product as the roof box has been re-imagined into a product that can take up multiple forms.

Creating a Logo

As the logo will often be seen on passing cars at a glance, it was concluded that a simple logo constituting only text would be most effective.

Target User

Something that has been a critical reflection point throughout the project was to design a product that anyone could own. Actively I wanted to increase the consumer market of current roof boxes. From a product for anyone with a car and sufficient storage space to keep one. To anybody who owns a car. By adding functionality, the user profile has been opened up to individuals who previously couldn’t afford to give up so much space to a product that carries no function. Ultimately home storage is something that people need all the time. Extra car storage is something that is required less frequently. A product that provides both will always be of use to its owner. There would be obvious marketing attention directed to more specific audiences such as young families and frequent campers.

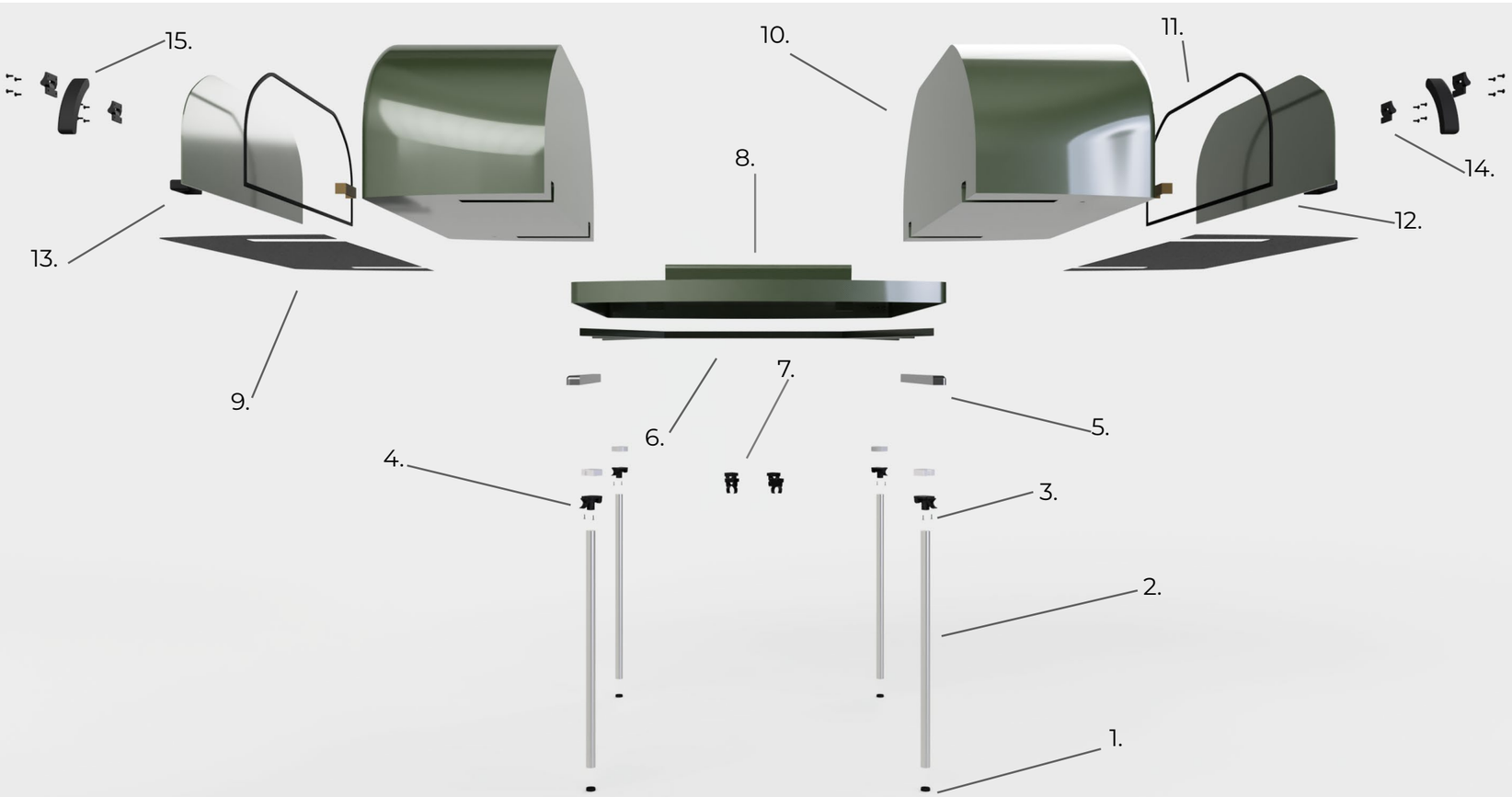
A Customisable Product

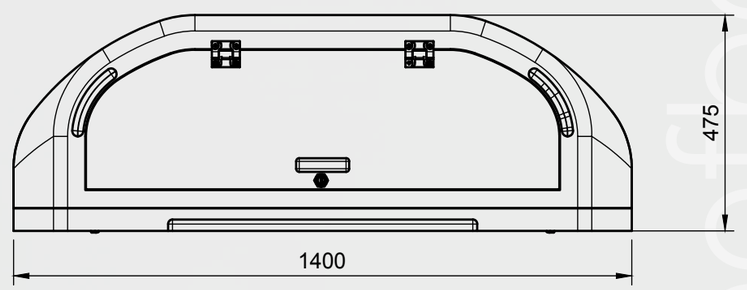
A big USP for the product over the market is its ability to be customised.

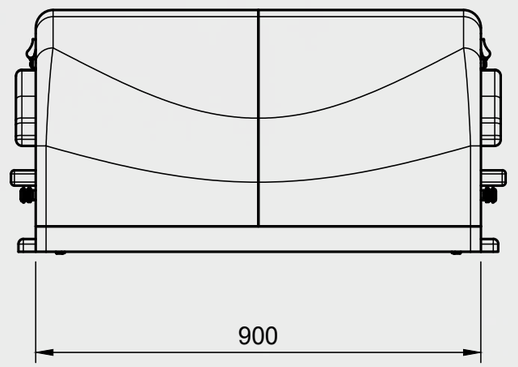
Why? People spend thousands of pounds customising their cars to meet personal taste and specifications. This in itself gives justification for the ability to customise a roof box given its position as a vehicle accessory. Furthermore, people might also be inclined to colour the product for its home storage function.

How? ABS was selected for many reasons, one of them being the wide variety of colour and texture variants available. The product’s mass customisation will be implemented through a considered UX/UI designed website environment from which the user orders the product. The website contains a visualisation of the product throughout the customisation process to ensure the user is ordering the right product for them.

Exploded view and Manufacture







Part Number	Qty	Part name	Material
1	4	Rubber foot	Rubber
2	4	Table leg	Aluminium
3	8	M3 Screw	Steel
4	4	Table leg hinge	Nylon Plastic
5	2	Vehicle connection point	ABS Plastic
6	1	Structural Ribbing	ABS Plastic
7	4	Table leg clip	ABS Plastic
8	1	Base/Table	ABS Plastic
9	2	Fabric carpet	Alcantara
10	2	Container	ABS Plastic
11	2	Gasket seal	Rubber
12	2	Door	ABS Plastic
13	2	Outer handle	ABS Plastic
14	4	Friction hinge	Nylon Plastic
15	4	Installation handle	ABS Plastic

Base Manufacture

The vacuum forming process has been identified as the most effective manufacturing method for the base sections of the product. This is formed in one piece from sheet ABS. Draught angles have been added to ensure that the base can accurately be taken from the mould. After vacuum forming is complete, the other components such as hinges, legs and structural ribbing can be installed. This process is standard practice throughout the current roof box industry

Container Manufacture

Two potential manufacture processes were identified for the container section. Both rotational moulding and vacuum forming were adjudged to be acceptable methods for manufacture. Rotational moulding has been selected as the primary method due to its ability to create complete hollow structures with inexpensive tool creation. It must be noted that this is a complex manufacturing method, and further development with a rotational moulding engineer would be required to prepare the product for manufacture.

Environmental Considerations

The biggest impact on the environment that a roof box has is its negative effect on fuel economy. In the design of Proteus, aerodynamic optimisation has negated this issue to an acceptable level. Furthermore, the product's function encourages the user to take it off the car when not required. The recycling of ABS has been considered, especially when vacuum forming, where it will be ensured that all waste materials are recycled sufficiently.