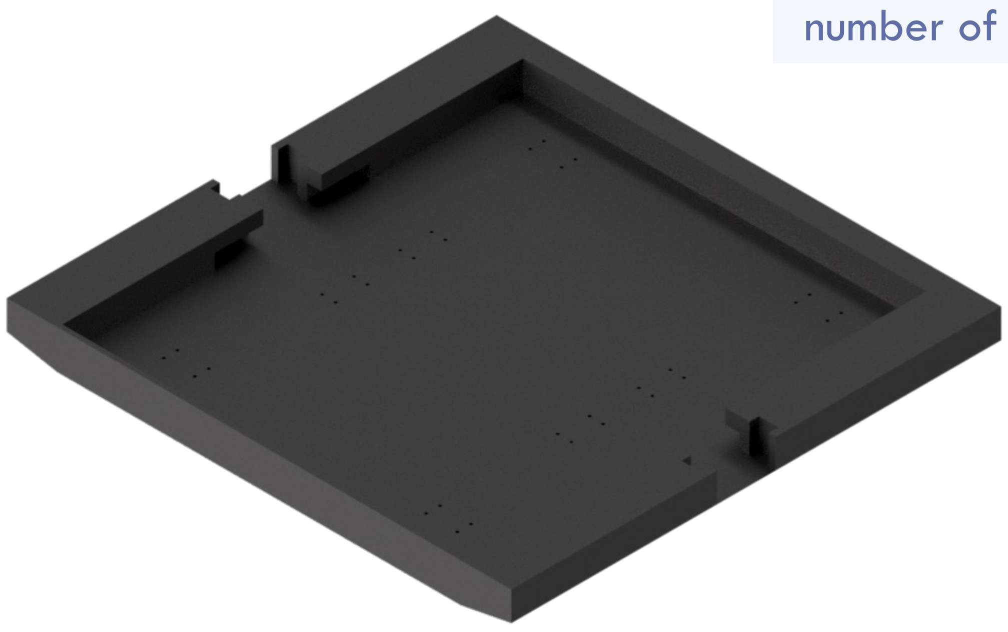
Materials, Manufacturing & Eco-Audit

Component

It is important to examine the material selection and manufacturing processes throughout the design of any product. The environmental impact of these two factors must also be assessed and minimised wherever possible without compromising functionality. The main base of the mobility aid was analysed as it is the largest component and requires the greatest number of manufacturing operations. Therefore, it is likely to contribute the most to the CO_2 emissions of the product.



Material Requirements:

D/W	Product Requirement	Material Requirement
D	When supporting a 90kg person (Terry), the system shall not break	Strong
W	The system shall be light	Low Density
D	The system shall be made of non flammmable material	Not Flammable
W	The system shall come in different colours	Customisable
D	The system will not be fragile	Strong, Resistant to wear
W	The system shall be easy to mass manufacture	Readily available, good manufacutring properties
W	The system should be discrete	Aesthetic Material
W	The sysetem should be built from recyclable eco-friendly materials	Reusable or low energy to produce
D	The system shall be affordable	Easy to manufacture, low price per kg

Materials

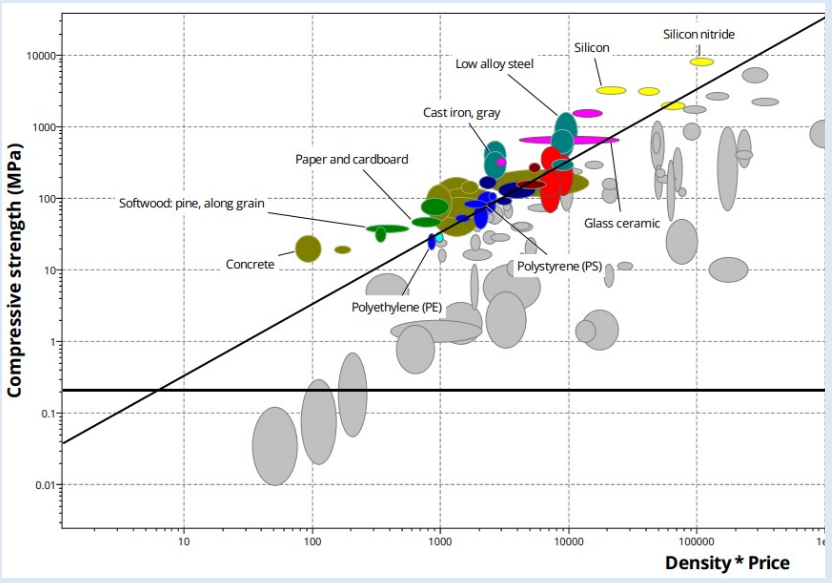
To select a single material from which to manufacture the base of the device, a combination of selection by analysis, synthesis and similarity was used.

Selection by Analysis

To screen the potentially suitable materials, the geometry of the base was considered and a merit index derived:

$$Merit\ Index = \frac{\sigma_c}{\rho * \frac{£}{kg}}$$

where σ_c represents the compressive strength of the material. By maximising the merit index, the performance of the material for this application is also maximised.



Applying a safety factor of 1.5, it was calculated that a material with a minimum σ_c of 22,000 Pa is required. The Ashby chart provides a screen of materials that meet these initial strength and cost requirements.[1] However, some screened materials are intuitively unsuitable for use. For example, concrete is not easily processed into the relatively precise geometry required and paper/cardboard do not possess the required fatigue strength.

Selection by Synthesis

Four families of materials were selected from the screening: Softwoods, plastics, foams, and steels. Selection by synthesis allows further narrowing of these materials.

Two products with similar required properties were selected for comparison: bicycle helmets and garden furniture. Both must be lightweight for comfort and portability while also being resistant to compressive forces – ensuring protection in an accident and the ability to support weight. Finally, they must be easy to mass-manufacture with precise geometry to meet the large market demand.

Helmets are generally made from an expanded polypropylene (EPP), a type of foam. Garden chairs are typically made from polypropylene, a thermoplastic.

Selection by Similarity

The main body of children's booster seats is usually made from a blend of various thermoplastics and foams. This often includes high-density polyethylene (HDPE), a durable and shock absorbent material.

These selection techniques emphasize that foams and polymers are generally more suitable than metals and woods. They are easy to recycle and require less energy to process. For instance, an aluminium part would likely have to be cut, bent, machined and drilled, whereas a thermoplastic can be easily moulded and then drilled. They can also be readily modified to meet aesthetic requirements, offering greater design flexibility.

Although EPP largely meets the design's requirements, due to the assembly of the product requiring bolts, it is not a suitable choice as the bolts will wear through the foam over time. If polypropylene is used, the base will have a mass of 3.64 kg and cost £4.00 whereas if it were to be HDPE, the mass would be 3.86 kg and cost £3.44. Furthermore, in the primary material production of each part, HDPE would release only 8.5 kg CO_{2e} whereas PPE would release approximately 10.6 kg CO_{2e}.[1] This makes HDPE the most suitable material for this component.

Manufacturing

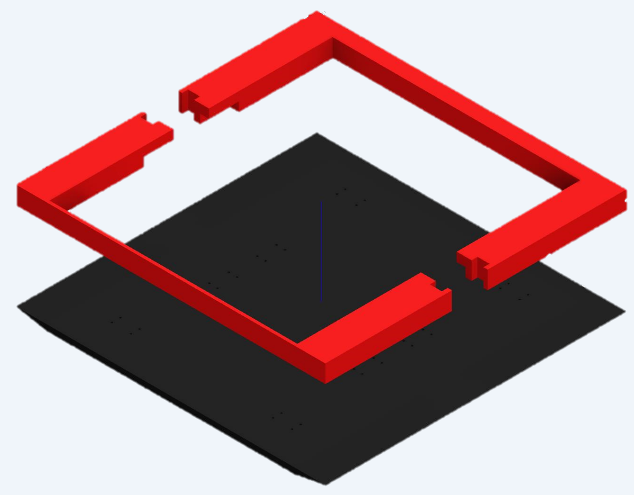
Market research indicates that products with a similar purpose often sell more than **1,000 units per month.** [4]

Following the process selection workflow, the first step was to estimate the required production quantity. Assuming, the product sells at a similar rate to its competitors, it is estimated to sell approximately 15,000 annually.

Considering the geometry, the desired material of the product and the required quantity being between 10,000 and 100,000 units, the Process Information Map suggests that suitable manufacturing methods may include: Injection Moulding, Compression Moulding and Vacuum Forming. [5]

Vacuum forming would be unsuitable for the parts shown in red as the geometry which holds the button is too complex. Compression Moulding would be a suitable process to manufacture this part. However, Injection Moulding would yield a better surface finish, its cycle time is shorter, and the material waste would be reduced.

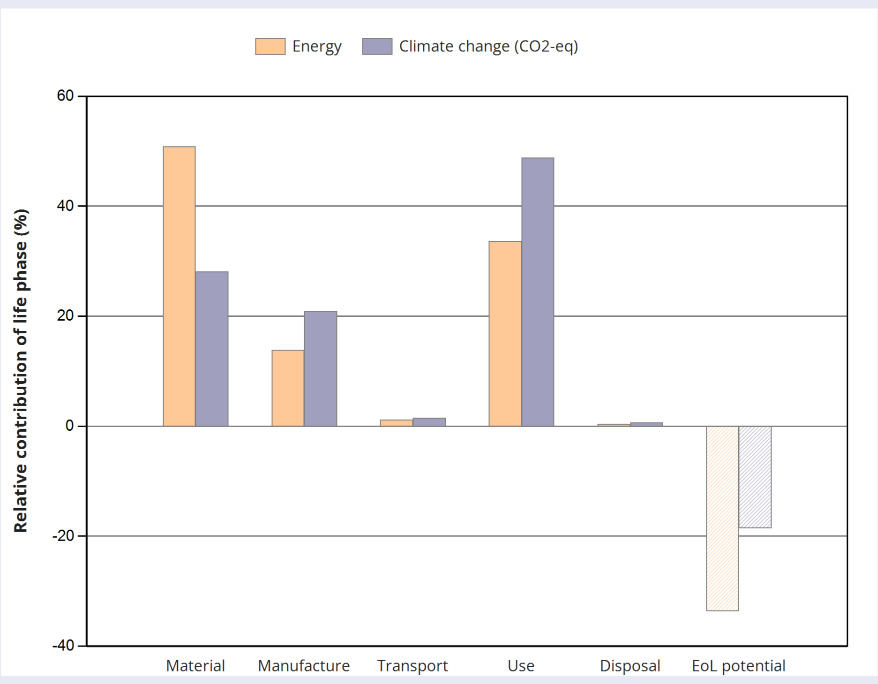
Due to the internal recess, it would be impossible to Injection Mould the entire part in one piece. Therefore, the three components shown below will be injection moulded and assembled using adhesive bonding.



The primary method for manufacturing for this component will be Injection Moulding. As there is an internal undercut in this piece, a standard injection Moulding process won't be sufficient. The component will be manufactured in 3 sections - the base and the two internal recesses. These pieces will then be joined by adhesive bonding and a drilling operation will create the holes for the spring bearings.

Finally, Envirograf's 3-2-1/S can be used to coat the HDPE to ensure it meets non-flammable safety requirements. [6]

Eco-Audit



This eco audit was conducted by using HDPE as the material for the component. It was assumed that the piece would have a mass of 3.86kg and that it would be transported on average 500 km from the factory to a store. Additionally, the product will be used on average 208 days a year (4 days a week) for an average of 30 km of travel per use. It was estimated that the average life cycle for the component will be 5 years. Due to this extensive usage, overall, the life phase of the product emits the most CO2 and is the most energy intensive.

Phase	Energy (MJ)	Energy (%)	Climate change (CO2-eq) (kg)	Climate change (CO2-eq) (%)
Material	310	50.9	8.48	28.1
Manufacture	84.4	13.9	6.34	21.0
Transport	7.04	1.2	0.467	1.5
Use	205	33.6	14.7	48.8
Disposal	2.7	0.4	0.189	0.6
Total (for first life)	**608**	**100**	**30.2**	**100**
End of life potential	-205		-5.6	

Potential redesigns

Based on the eco audit, one redesign could be reducing wall thickness on this component to use less material. This implies that less energy is used, and less CO2 is emitted when manufacturing the product.

A more sustainable material could be used in future iterations, but this may increase weight, cost, and manufacturing difficulty.

References:

1. *Ashby MF. Granta EduPack [database on the Internet]. Cambridge: Granta Design; [cited 2025 Feb 10]. Available from: https://www.grantadesign.com/*
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3. *MM STORE LTD. Children's Plastic Chair W 35.5cm x D 34cm x H 50.5cm Assorted Colours 8301 / 9101 A. Available from: https://www.mmstore.co.uk/products/kids-chair-9101. [Accessed 10 Feb 2025].*
4. *Car Door Handle Aid for Elderly. Amazon UK. Available from: https://www.amazon.co.uk/Car-Door-Handle-Elderly/dp/B09HWW6TYV. Accessed: 2025 Feb 10.*
5. *Selection of material process [Internet]. ScienceDirect; [cited 2025 Feb 10]. Available from: https://www.sciencedirect.com/topics/materials-science/selection-of-material-process*
6. *3-2-1 Special [Internet]. Envirograf; [cited 2025 Feb 10]. Available from: https://envirograf.com/product/3-2-1-special/*