Material selection

Material selection is a critical step in the design process, aiming to identify the optimal material based on specific objectives, constraints, and free variables. Proper material selection ensures the production of a durable, functional product that meets design requirements while minimizing cost and environmental impact. For this design, the Granta Edupack software was utilized. In total, there are seven subsystems to consider, four of which already have an established material. Therefore, material selection needs to be conducted for the three remaining subsystems.

Compaction system

The compression system experiences the most significant mechanical stresses. The exact nature of these stresses must be identified. For practical purposes, the arms of the scissor lift will be modelled as rectangular beams with a length L, height h, and thickness e. In this model, h is treated as a free variable.

The scissor lift must withstand bending M caused by the forces on its arms and fatigue σ_f due to multiple compression cycles. Additionally, it requires high resistance to crack propagation, which means the material must have high toughness. The objective is to select a lightweight material, and the objective function is defined as:

$$m = \rho L h e$$

The following constraint equations must be satisfied:

$$\delta_{max} = \frac{M_{max} L^2}{4EI} = \frac{3qL^4}{2eEh^3} \; leading \; to \; h = \sqrt[3]{\frac{3qL^4}{2eE\delta_{max}}}$$

$$\sigma_f \geq \sigma = \frac{My}{I} = \frac{M\frac{h}{2}}{\frac{eh^3}{12}} \; leading \; to \; h = \sqrt{\frac{6M}{e\sigma}}$$

Where q is the distributed load on the beam, and δ_{max} is the maximum displacement. By substituting the free variable into the objective function and eliminating terms unrelated to material properties, it is possible to define two performance indices:

$$M_1 = \frac{\sqrt[3]{E}}{\rho} \; and \; M_2 = \frac{\sqrt{\sigma}}{\rho}$$

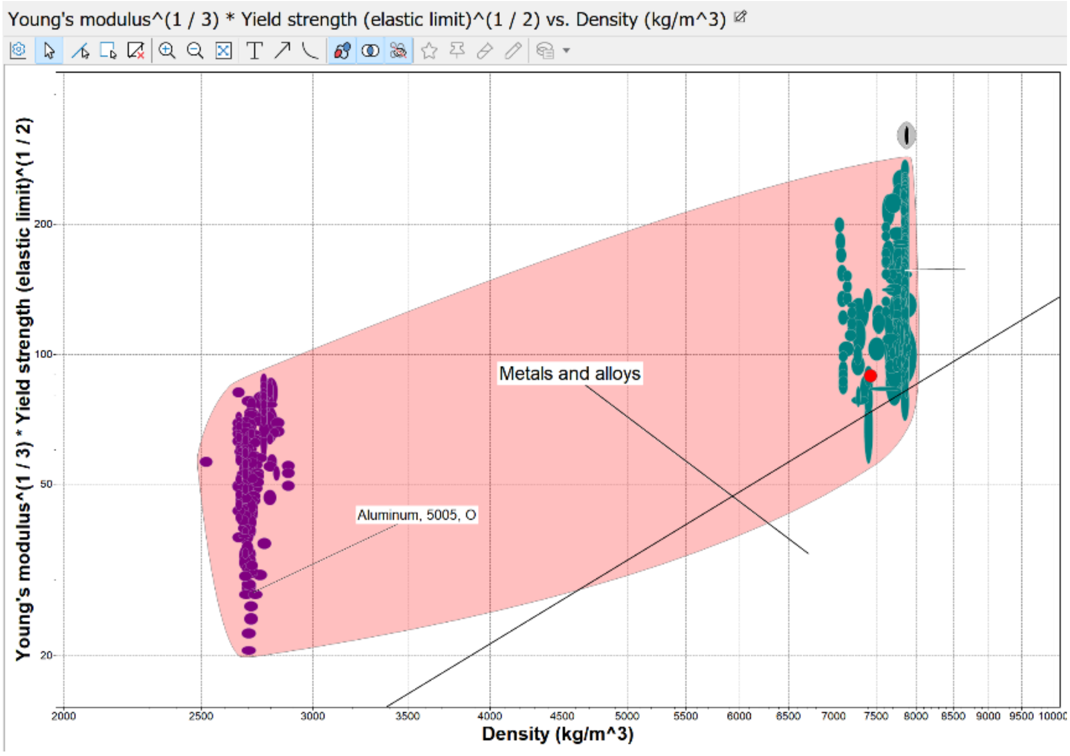
The goal is to maximize both performance indices. To account for both contributions, they are combined into a single global performance index:

$$M_{Global} = M_1 M_2 = \frac{\sqrt[3]{E}\sqrt{\sigma}}{\rho^2}$$

The global index can also be expressed in logarithmic form:

$$\log\left(\sqrt[3]{E}\sqrt{\sigma}\right) = 2\log(\rho) + \log\left(M_{Global}\right)$$

This relation allows the creation of a performance chart:



Based on this analysis, the compression system will be constructed using 4mm-thick aluminium (e.g., 5005 or 3003). Aluminium has the advantage of having a low density compared to other metals, which minimizes the mass of the system while maintaining structural integrity. This is critical for a scissor lift, where reducing the moving mass improves performance and efficiency. Moreover, this material has relatively simple manufacturing processes.

Outer structure

The outer structure is the part that covers the entire trash bin, making it the most exposed to external elements. This section is modeled in the same way as the previous one.

To select the best material, we must consider the internal compaction system, which can generate bending moments M on the outer structure. These moments result in mechanical stress that the outer structure must withstand without permanent deforming. Additionally, since this part requires a large amount of material, it is preferable to minimize its cost C as much as possible.

The overall objective is to minimize both cost and mass, leading to the following objective function:

$$mC = C\rho Lhe$$

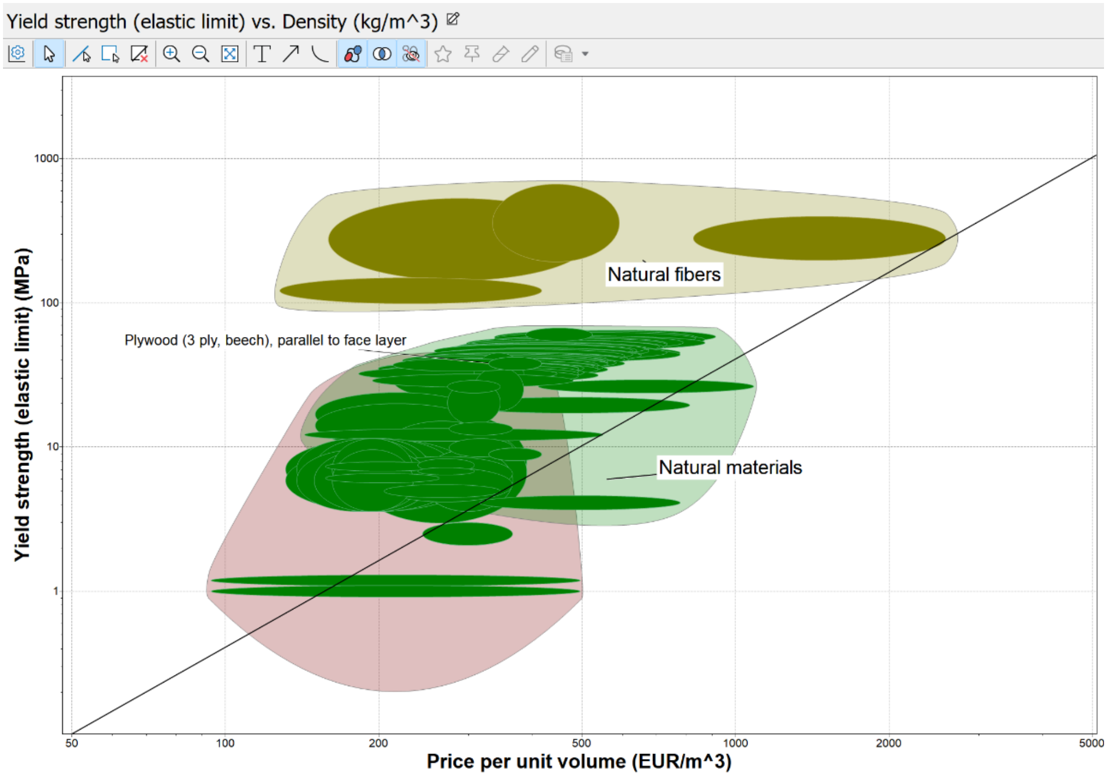
Using the bending equation derived earlier, we have:

$$M = \frac{\sqrt{\sigma}}{C\rho} = \frac{\sqrt{\sigma}}{p}$$

where p represents the cost per cubic meter (volumetric cost). It is possible to express the performance index in logarithmic form:

$$\log(\sigma) = 2\log(p) + 2\log(M)$$

This relationship allows for the creation of an Ashby diagram to visually analyze material performance:



Based on this analysis, an 8mm-thick plywood with a protective coating was selected for the outer structure. Plywood is easy to cut, shape, and assemble, making it highly practical for large-scale production. It is also compatible with standard coatings and finishes for added protection and aesthetics. Moreover, Plywood is a renewable resource, making it a more environmentally friendly option compared to plastics or metals, provided it is sourced responsibly.

Trash bin

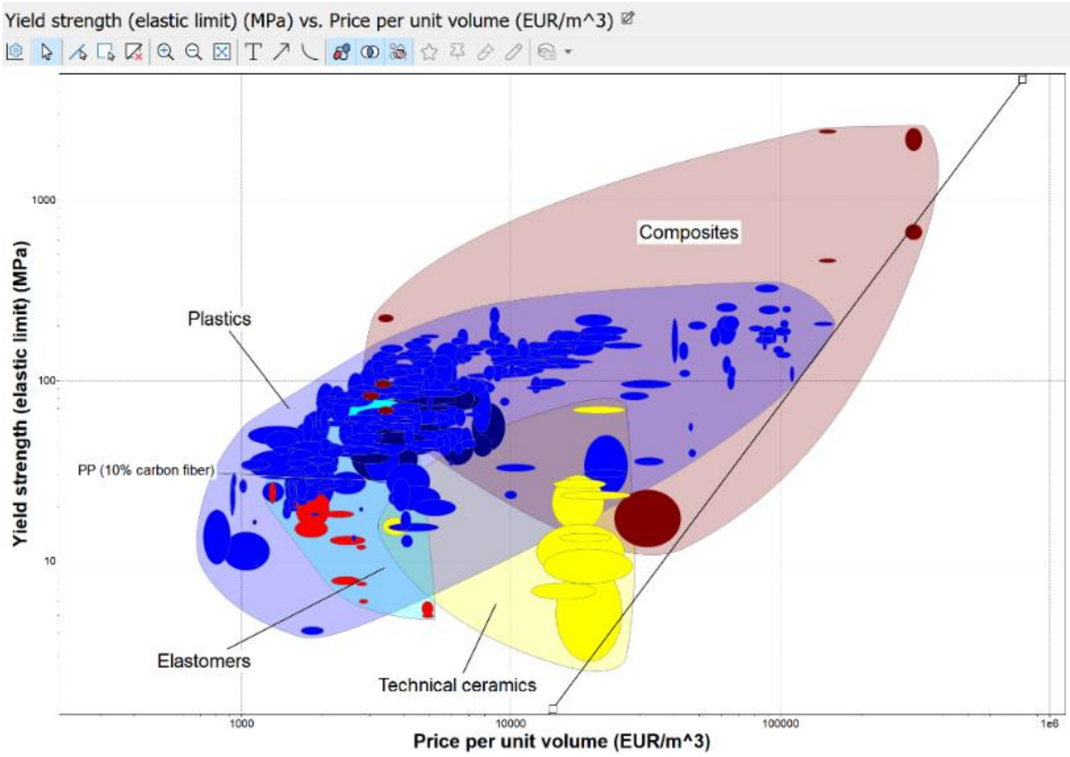
This section refers to the removable bin where all compacted waste is collected. Its analysis follows a methodology like that of the outer structure, with additional critical consideration.

The removable bin is subject to significant exposure to food waste and liquids, which can stagnate at the bottom over time. Such exposure presents a risk of chemical degradation and potential long-term damage, necessitating a material with high resistance to corrosion and chemical interactions. This is especially important for ensuring durability and hygiene, as the bin must withstand frequent contact with organic matter and cleaning agents.

To address these challenges, a corrosion-resistance criterion was introduced into the material selection process using Granta Edupack. From the earlier analysis, the following logarithmic equation was used for the bin's material selection:

$$\log(\sigma) = 2\log(p) + 2\log(M)$$

This equation is used to evaluate the performance index for material selection and results in the following Ashby diagram:



Based on this analysis, The material selected for the trash bin is a thermoplastic such as polypropylene. Polypropylene is suitable for processes such as injection molding or extrusion, enabling efficient production of the bin with complex geometries if needed.

Manufacturing processes

The manufacturing process is a critical component, as it defines how the materials selected in the previous section will be produced. By combining various manufacturing technologies, we ensure that the process is easy to execute and cost-effective for mass production of the trash bin components.

For the aluminum, which forms the **compaction system**, it will initially be made from a thick sheet of aluminum alloy. A milling step will be performed to refine the dimensions, edges, and thicknesses of the parts. A stamping process will be used to create the necessary holes for assembly markings and connections with other subsystems.

The **external structure** of the trash bin will be primarily constructed from plywood, which will first be manufactured to the correct dimensions at a woodworking workshop. This method is chosen for its cost-effectiveness in producing large panels. Once the plywood pieces are cut to size, a series of finishing steps will ensure both durability and aesthetic appeal. First, the plywood will undergo sanding to smooth out the surface, removing any roughness. Following this, a primer will be applied to reduce moisture absorption and improve the adhesion of the final finish. The final protective coating will be applied to enhance the material’s resistance to scratches, stains, and wear, ensuring that the exterior remains attractive and durable throughout its lifespan.

The **main body of the trash bin** will be made from polypropylene, a versatile and durable plastic. This material will be processed using injection molding technology, which involves heating the polypropylene to its melting point and injecting it under pressure into a mold to form the desired shape. Injection molding was chosen for its ability to produce parts with high precision and complex geometries in large quantities. This technology offers significant advantages for manufacturing the trash bin’s body.