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Design for Manufacture and Assembly: Mobile
Phone Housing Optimisation

ACMA5002

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Abstract

The purpose of this report is to optimise the production process of a mobile phone housing for high-volume polymer injection moulding. Customer requirements were first identified and incorporated into the design process through Quality Function Deployment (QFD) while Failure Mode and Effects Analysis (FMEA) was utilised to support design development and reduce potential design risks. To identify a suitable material for the mobile phone housing, a material selection study was completed using Granta Edu Pack, where TPO was identified as the most suitable material due to its engineering properties such as density, elongation and suitability for polymer injection moulding.

The design was created in Autodesk Fusion 360 and developed using injection moulding simulations and Design of Experiments (DOE) investigations to reduce defects such as weld lines, sink marks and warpage. The final design configuration was selected based on the lowest number of defects predicted during the simulation studies. Alongside this, Finite Element Analysis (FEA) was also conducted using loads ranging from 10 N to 50 N to assess the structural performance of the housing. The final design remained lightweight at 25.7 g whilst maintaining a low manufacturing cost of £0.184 per unit. The break-even analysis showed that approximately 926 units would need to be sold to recover the initial tooling investment.

The final design demonstrated that a lightweight and cost-effective mobile phone housing can be successfully designed for high-volume manufacture whilst meeting the majority of the customer requirements. Design for Manufacture (DFM) and Design for Assembly (DFA) principles were incorporated throughout the design process to improve manufacturability and reduce assembly complexity.

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1. Introduction

1.1 Purpose of the Report

The purpose of the report is to optimise the manufacturing process of a mobile phone housing, whilst aligning with DFM and DFA principles. The mobile phone housing will be manufactured from an injection moulding process, and analysis will be undertaken to ensure product quality and evaluate the structural stresses experienced during operation. Important parameters such as material choice, sustainability and cost will also be analysed for further optimisation of the manufacturing process.

1.2 Problem Definition

Designing a mobile phone housing unit for manufacturing by polymer injection moulding can present various challenges for an engineer. Various defects such as warpage, shrinkage, sink marks, weld lines and air traps can cause significant quality issues and production costs if not correctly mitigated during the design phase. Furthermore, designing a mobile phone case requires the CAD model to be modelled with appropriate wall thicknesses and dimensions. Inefficient mould designs in CAD can lead to defects within the mould causing further tooling costs in re-designing and injection moulding.

1.3 Scope and Methodologies

To successfully carry out the purpose of the report, multiple methodologies will be implemented throughout. QFD will be utilised to transpose customer requirements into key engineering attributes. To mitigate any issues arising during manufacturing and design, FMEA will be utilised to identify any risks with appropriate rankings to understand the necessary prevention controls.

In addition to this, the use of Autodesk Fusion 360 provides access to tools that allow for further prevention of defects in the design stage. The use of Plastics analysis allows for investigation into polymer injection moulding to understand material flow behaviour as well as cooling performance to understand the chance of defects within

the mobile phone housing. In conjunction with this, FEA provides a simulated version of different operating conditions to evaluate its structural performance. Furthermore, cost and sustainability calculations allow for comparison of the product's economic validity and its environmental impact.

2 Literature Review

2.1 Design for Manufacture and Assembly

DFM and DFA are key characteristics for improving the efficiency of a product within its design stage. According to Formentini et al. (2022), DFA is a methodology used to improve assembly efficiency through the reduction of components and critical assembly tasks, while DFM aims to simplify manufacturing processes and reduce production costs through the selection of appropriate raw materials and dimensional and geometrical tolerances. Furthermore, Formentini et al. (2022) found that DFMA methods are primarily used during the detail and embodiment design phases of the product development process. The effectiveness of DFMA has been demonstrated through industrial case studies. Nurul Ain Maidin et al. (2018) redesigned a water nozzle using DFMA principles, reducing the number of components from 13 to 8 and lowering assembly time from 51.7s to 28.3s. This resulted in an increase in DFA efficiency from 23% to 25%. As a result, DFMA methodologies were implemented throughout the design of the mobile phone housing unit to improve manufacturability whilst reducing assembly complexity and associated manufacturing costs.

2.2 Manufacturing Techniques

To manufacture the outlined mobile phone housing, a polymer injection moulding manufacturing process was chosen. According to Alexandre-Franco et al (2024), injection moulding is a mass production technique where molten polymer is injected into a mould cavity under high pressure and once the polymer cools and solidifies, the mould is open and the part is ejected. This highlights its suitability for mass production and polymer-based products, making it a suitable manufacturing process for the mobile phone housing. When analysing relevant manufacturing processes, additive manufacturing (AM), such as 3D printing, was considered as a potential alternative method. However, according to Jung et al. (2023) injection moulding is more cost effective than AM when manufacturing at higher production volumes. This further justifies the selection of polymer injection moulding for the optimum manufacturing process.

Despite the benefits of polymer injection moulding, manufacturing defects can occur during the process. Common defects include sink marks, short shots, weld lines and

warpage, all of which can negatively affect the quality of the final component. These defects may increase production costs and lead times due to the need for design modifications or rejection of defective parts (Achor et al., 2024). This outlines that analysis during the design phase and the use of simulation tools are vital to ensure the quality and manufacturability of the mobile phone housing.

2.3 Analysis Tools Overview

To aid the manufacturing and design process, multiple tools were used in conjunction for analysis. According to Mao et al. (2025), QFD is a product planning approach utilised to transform customer requirements into engineering characteristics during the product design and development. Furthermore, implementation of QFD can shorten cycle times, reduce costs and improve quality, whilst also increasing customer satisfaction (Mao et al. 2025). However, attempting to utilise QFD within the design phase can present challenges, especially if the customer surveys or market research are not descriptive to understand fully the customers desires of the product (Edgar, 2023).

To understand risks within the process, FMEA can be used which is an “engineering methodology used to identify potential failure modes, evaluate their effects on operation and determines procedures to mitigate these failures” (Shetwan et al. 2025). FMEA is commonly adopted within the manufacturing sector, which enables a company to assess and outline failures in the process before production which prevent failures occurring costing resources (Shetwan et al. 2025). Nevertheless, a limitation of FMEA is the variation in assessments when prioritising risks due to differing expert opinions, which may reduce the effectiveness of the risk analysis process (Liu and Tang, 2022).

To further support the manufacturing process of a mobile phone housing, Autodesk Fusion 360 Plastics Simulation is a valuable tool for understanding the injection moulding process. According to Hyvärinen et al. (2020), a major advantage of using injection moulding simulation software is that manufacturers can "prevent and identify defects before a part has begun production". However, the accuracy of injection moulding simulation software is dependent upon several factors, including

part geometry, mesh density, material properties and process parameters, which may affect the reliability of the simulation (Speight et al., 2008)

DOE can be utilised within a manufacturing process to determine how different process factors affect product quality and identify optimum operating conditions (Sheriff Lamidi et al., 2024). Furthermore, DOE enables a company to identify key variables which can improve product quality and reduce variation during production. However, when implementing DOE, resource constraints such as time and budget can present challenges to a company during the manufacturing process (Sheriff Lamidi et al., 2024).

Understanding how the mobile phone housing will operate in its intended operating conditions is essential. FEA is a simulated technique to understand how a product responds to various factors such as stress and vibration and whether it will fail against its intended use (Autodesk, 2026). Utilising simulation software provides engineers with the opportunity to identify and mitigate potential structural defects before manufacturing, reducing the need for multiple physical prototypes and minimising wasted resource (Autodesk, 2026). Despite this advantage, when using simulation software for FEA, the results are based on numerical approximations and may not be completely identical to real-world conditions (SimScale, 2024).

3 Customer Requirements

3.1 Performance Attributes

To ensure the mobile phone housing meets key customer requirements, the relevant design criteria must be established during the design stage. Table 1 summarises the requirements identified for the final product.

Table 1: Mobile phone housing performance requirements

Performance Requirements	Definition	Engineering Characteristics
Impact Resistance	Able to withstand accidental drops without cracking or permanent deformation.	Withstand drops for average user height without structural damage leading to fatigue
Manufacturability	Able to be manufactured easily while being consistent and economically positive.	Must be suitable for high volume injection moulding with minimal production defects.
Lightweight	Able to be comfortably held by the user whilst still providing adequate protection.	Low density material with uniform wall thickness of between 1.5mm to 2mm
Durability	Able to withstand long-term use without significant wear, fatigue or structural failure.	Manufactured to be resistant to wear, fatigue and operating conditions until its end-of-life cycle.
Surface Quality	Able to be manufactured with a high-quality surface finish suitable for a premium smartphone product.	Minimal sink marks and weld lines to reduce visible defects.
Component Fit	Able to be manufactured to outlined dimensions of the CAD model to maintain correct component fit.	Minimise warpage and dimensional variation to ensure components fit correctly during assembly.
Cost Effective	Able to be manufactured at a reasonable cost whilst maintaining product quality and performance	Low material and manufacturing costs for high volume polymer injection moulding

Table 1 outlines the balance between manufacturing and consumer considerations required for the mobile phone housing. Characteristics such as durability and impact resistance ensure that the housing provides adequate protection during everyday use, whilst remaining lightweight and comfortable to handle. Surface quality and component fit are vital to ensure the manufactured product functions as required and

produced with a high level of quality. Manufacturability is also a key attribute due to the fact the mobile phone housing design must be suitable for high volume polymer injection moulding, whilst consistently maintaining a low production cost and minimal defect rate.

3.2 QFD Application

To understand the optimised manufacturing factors to meet customer demands, QFD was implemented to help translate these needs into measurable technical specifications. Figure 1 outlines this process.

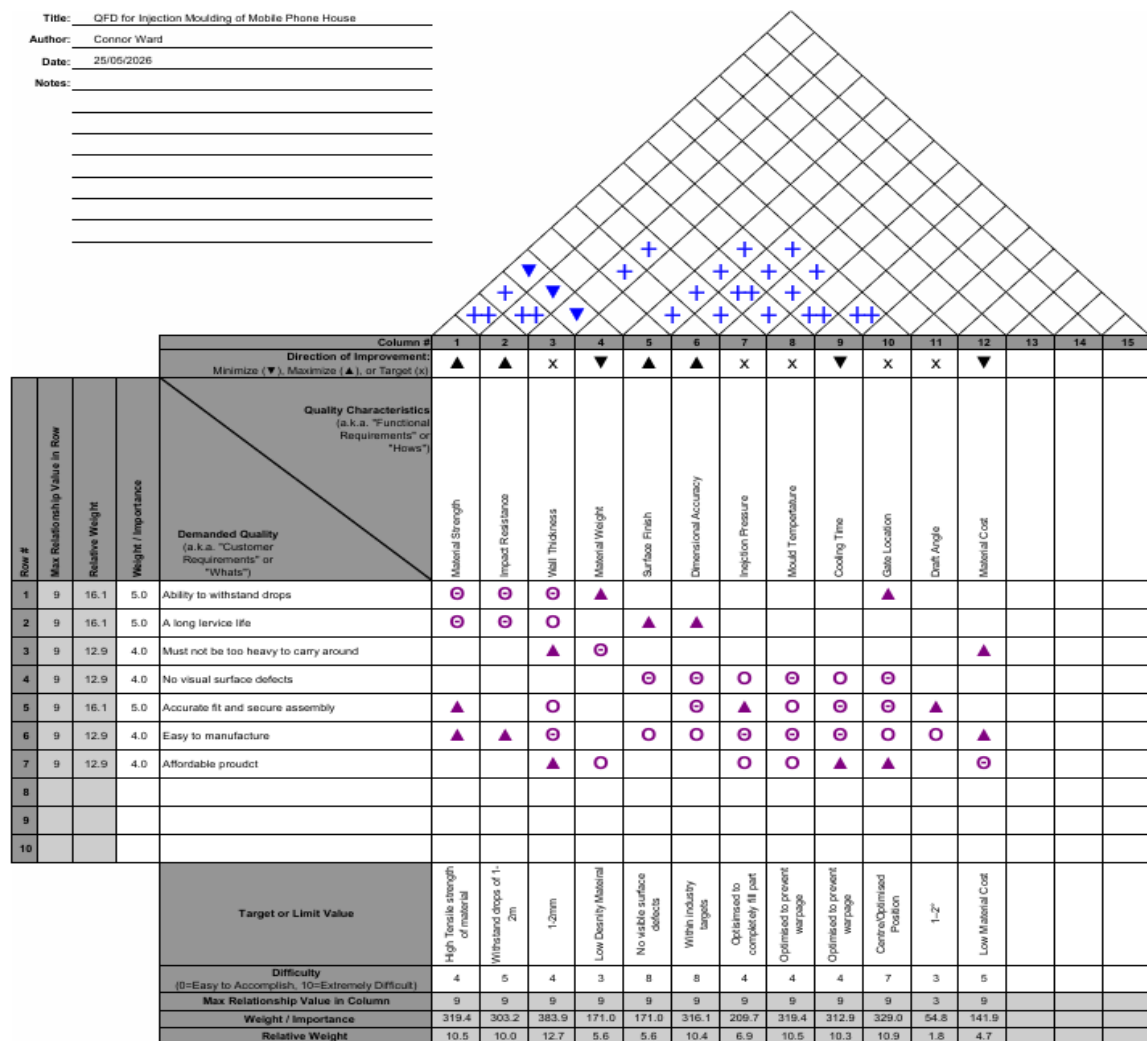


Figure 1: QFD matrix for the mobile phone housing design

From Figure 1, the customer requirements can be compared against the key engineering characteristics involved in the design and manufacture of the mobile phone housing. The QFD analysis identified wall thickness (12.7%), gate location

(10.9%), material strength (10.5%), mould temperature (10.5%), dimensional accuracy (10.4%) and cooling time (10.3%) as the most important engineering characteristics. This highlights how both the material selection and injection moulding process have a significant effect on the overall performance and quality of the mobile phone housing. Impact resistance (10.0%) also achieved a high weighting due to its importance in protecting against accidental drops and normal operating conditions.

3.3 FMEA Application

To ensure that mobile phone housing is manufactured successfully, FMEA was implemented to analyse any potential risks to the polymer injection moulding process and the relevant mitigation controls required. Table 2 highlights the potential failure modes within the manufacturing of the mobile phone housing.

Table 2: Process FMEA of the mobile phone housing

Process Function	Potential Failure Mode	Potential Effect(s) of Failure	S e v	C l s s	Potential Cause(s)/ Mechanism(s) of Failure	O c c	Current Process Controls	D e t	R P N	Recommended Action(s)	Action Results				
											Actions Taken	S e v	O c c	D e t	R P N
Injection Moulding	Warpage	Shrinkage of the part causing it not to fit the phone	8		Uneven cooling of the polymer or incorrect mould temperature	5	Polymer Injection Mould Analysis	4	160	Optimise cooling channels and mould temperature through DOE using Auto Fusion 360	DOE undertaken	8	3	4	96
Injection Moulding	Weld Lines	Visible weld lines on the surface and localised weakness in areas of the housing	6		Poor material flow into housing or poor gate placement	5	Polymer Injection Mould Analysis	4	120	Optimise gate location and material flow path through DOE using Auto Fusion 360 to minimise weld line formation.	DOE undertaken	6	3	4	72
Injection Moulding	Short Shot	Incomplete filling of the mould.	9		Insufficient injection pressure or poor gate location	4	Polymer Injection Mould Analysis	5	180	Increase injection pressure and optimise gate location through DOE using Auto Fusion 360 to ensure complete cavity filling.	DOE undertaken	9	2	5	90
Product Use	Housing cracking after being dropped	Reduced protection of the phone due to structural damage of the housing	9		Insufficient material choice.	4	Material Selection Process	4	144	Using Granta EDS to compare materials as well as FEA simulation	Granta EDS utilised and material compared with FEA to validate results.	9	2	4	72
Injection Moulding	Sink Marks	Surface defects reducing the product quality	6		Uneven wall thickness of the housing	4	Polymer Injection Mould Analysis	5	120	Ensure housing maintains a constant wall thickness validated by Auto Fusion 360 simulation	Uniform wall thickness maintained and DOE undertaken to reduce sink marks	6	2	5	60

Table 2 indicates the various risks identified during the manufacturing of the mobile phone housing. Failure modes such as warpage, short shot and housing cracking

after dropping were identified as the highest severity risks. Mitigation controls were outlined for each risk and implemented to reduce defects and improve the overall quality and performance of the product.

3.4 Design Optimisation (DOE)

To ensure that key design and processing variables were considered, a series of simulations were conducted investigating melt temperature, mould temperature, gate location, camera housing design, fillets and draft angles.

3.4.1 Baseline Design

Figure 2 outlines the baseline design which was used as the reference point for all optimisation studies. This design features a target wall thickness of 2.0mm, 1.5° draft angles and filleted edges to improve manufacturability. A raised camera is included to provide protection for camera modules (based on an iPhone 15), resulting in an increase of material thickness compared to the main body of the case housing.

To align with DFM and DFA principles, the mobile phone housing is designed as a single component subsequently eliminating the need for additional parts such as snap-on clips. Retention features are built into the side walls, allowing the phone to be pushed into the housing while remaining securely held in place.



Figure 2: Baseline design of the mobile phone housing in Autodesk Fusion 360

3.4.2 DOE Variables Investigated

To understand the most efficient process parameters for polymer injection moulding, multiple design variations were run and simulated. Table 3 highlights the various simulations run and what was altered between each simulation.

Table 3: Summary of DOE investigations of the mobile phone housing

Simulation	Variable Changed	Purpose
Attempt 1 - 3	Melt and mould temperatures	Reference simulation
Attempt 4	Same temperature variables as Attempt 1 – decreased localised material area of the camera bump by 0.3mm	Attempt to reduce Warpage within the design.
Attempt 5 – 8	Attempt 1 geometry – Multiple fillets investigated.	Improve flow and reduce stress concentrations
Attempt 9 - 12	Attempt 8 geometry – gate location moved	Improve flow of polymer and reduce defects.
Attempt 13 - 14	Attempt 8 geometry – draft angle increased from between 1° and 2° degrees	Improve Manufacturability.

After multiple iterations, Attempt 8 provided the most favourable balance between visual defects and warpage performance. This geometry was selected as the basis for the subsequent gate location and draft angle investigations.

3.4.3 DOE Variables Results

To understand the influence of each DOE variable on the injection moulding process, Table 4 outlines the most significant results obtained from each simulation study.

Table 4: DOE investigation results.

Attempt	Fill Time (s)	Visual Defects (Faces)	Maximum Warpage (mm)
1	0.52	34	0.663
2	0.52	40	0.667
3	0.52	33	0.666
4	0.52	35	0.668
5	0.52	41	0.665
6	0.52	35	0.665
7	0.52	39	0.665
8	0.52	29	0.665
9	0.84	35	0.675
10	0.74	42	0.653
11	0.95	30	0.673
12	0.52	32	0.657
13	0.52	38	0.667
14	0.52 (Short Shot)	31	0.665

Table 4 illustrates that Attempt 8 produced the lowest number of visual defects (29) while maintaining a similar fill time and maximum warpage to the other attempts. Other iterations achieved slight improvements in maximum warpage; however, this resulted in an increase in visual defects. This demonstrates why Attempt 8 was chosen as the optimum design, as it provided the best result of surface defects without increasing the warpage of the design.

Attempt 8 involved adding additional fillets into the internal side of the mobile phone housing where the camera bumps and flashlight sit. This was aimed at reducing the number of visual defects and warpage tolerance identified in the DOE study. The implemented improvements showed a decrease within visual defects, but maximum warpage stayed aligned with other simulations. This indicates that the additional fillets improved the overall design of the product. Attempt 14 provided confirmation that increasing the draft angle from the baseline design of 1.5° resulted in additional defects and ultimately resulted in a short shot. This indicates that increasing the draft angle beyond the baseline design negatively affected the filling of the mould cavity and was therefore not considered a suitable design modification.

The DOE study showed that the design changes and process temperature settings had more of an effect on visual defects than maximum warpage. The warpage values remained similar across all simulations at around 0.65 mm, while improvements in visual defects were achieved. Based on these results, Attempt 8 parameters were adopted as the final design.

4 Design and Development

4.1 3D CAD Models

Figure 3 illustrates the final mobile phone housing design developed in Autodesk Fusion 360, incorporating the design changes outlined in Section 3.4.3.



Figure 3: Final CAD model of the mobile phone housing developed in Autodesk Fusion 360.

This final design includes additional internal fillets around the camera housing, a raised camera surround for protection of the camera modules, integrated retention features within the side walls and functional cut-outs for the charging port, speakers and buttons. The design also incorporates a target wall thickness of 2.0 mm and 1.5° draft angles to improve manufacturability during polymer injection moulding.

4.2 Detailed CAD Drawing

A detailed engineering drawing was produced from the final CAD model and is shown in Figure 4. This includes the overall dimensions, wall thickness and section view of the mobile phone housing.

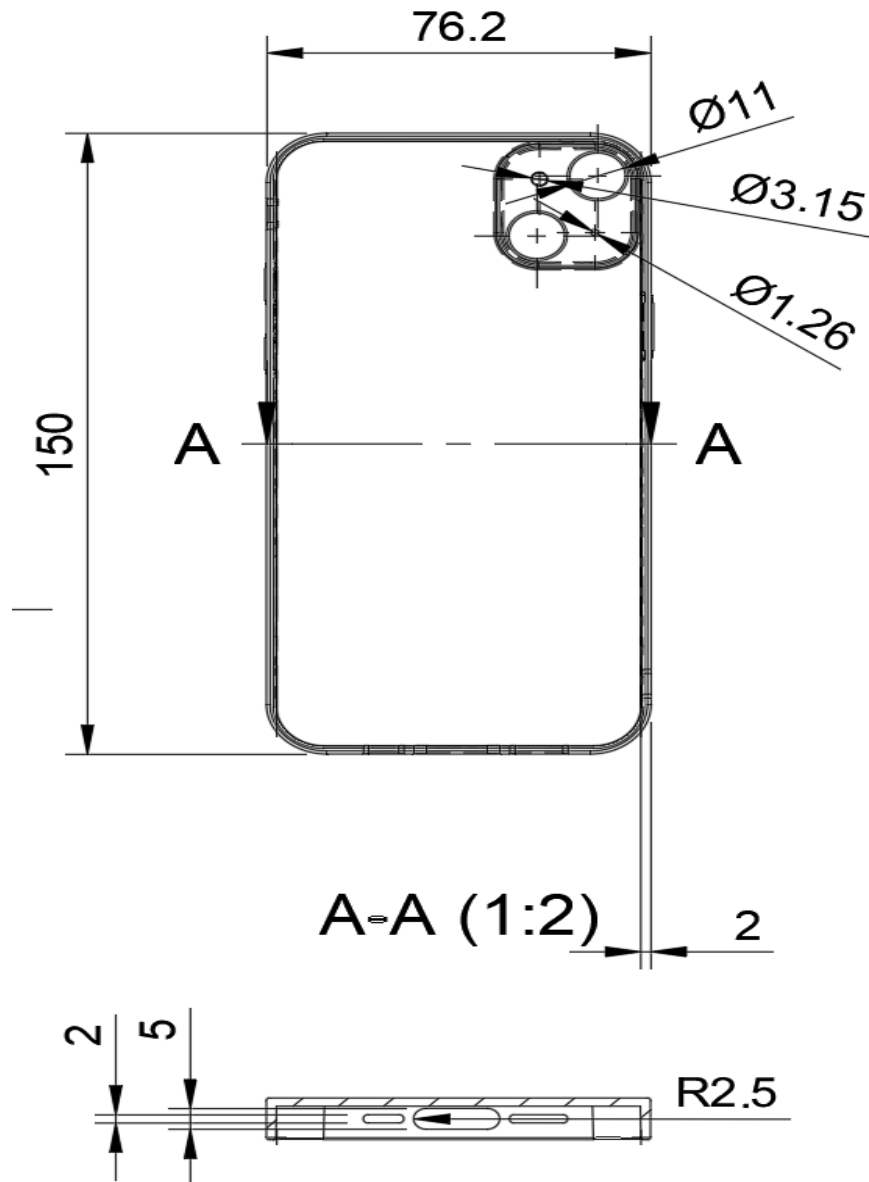


Figure 4: Dimension drawing of the mobile phone housing in Autodesk Fusion 360

4.3 Material Selection

To ensure that the mobile phone housing aligns with the performance requirements outlined in Section 3.1, Granta Edu Pack materials database was utilised to conduct an analysis study into the most suitable materials. Multiple configurations of criteria were set at each stage in the study which then prevented materials that were not suitable undergoing further analysis.

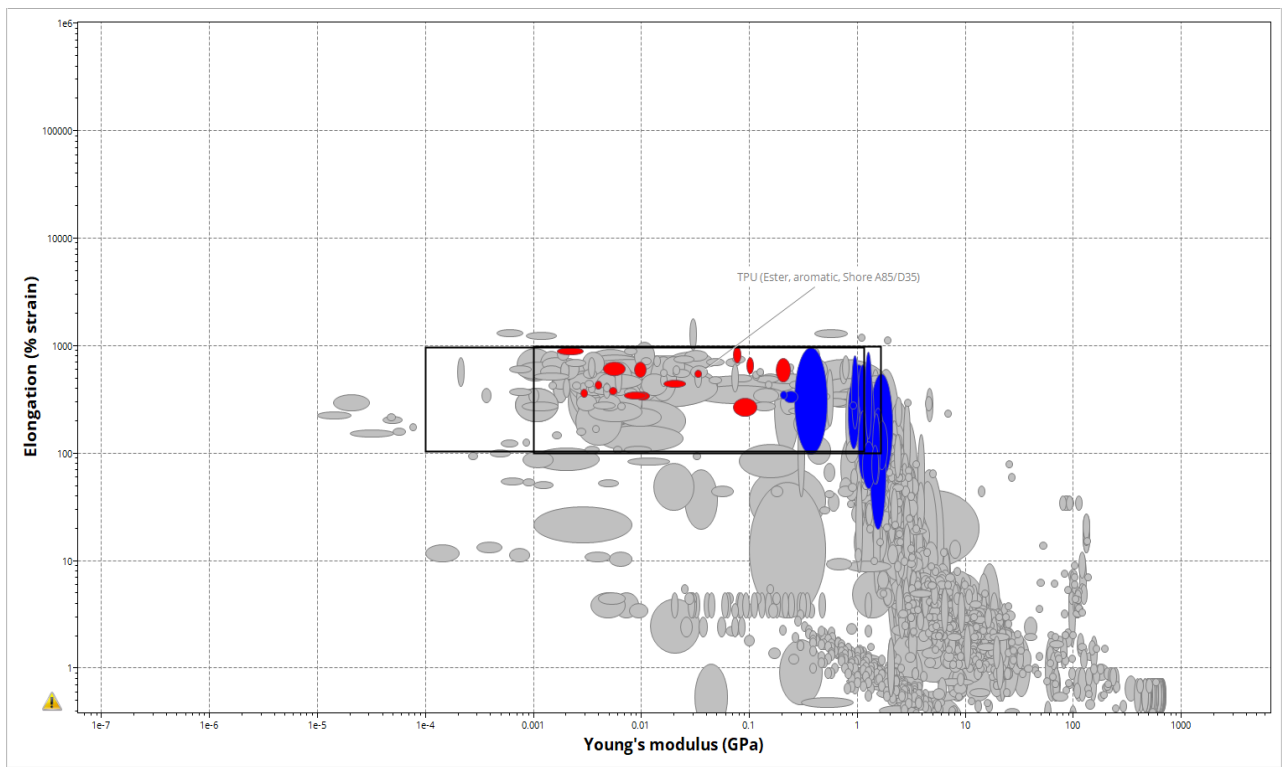


Figure 5: Ashby chart comparing young's modulus and elongation at strain.

Figure 5 shows the first material analysis between elongation and young's modulus. A criteria range of 100–1000% elongation and 0.001–2 GPa young's modulus was applied to identify materials capable of absorbing impact energy through deformation whilst maintaining sufficient stiffness to provide structural support and protection during everyday use.

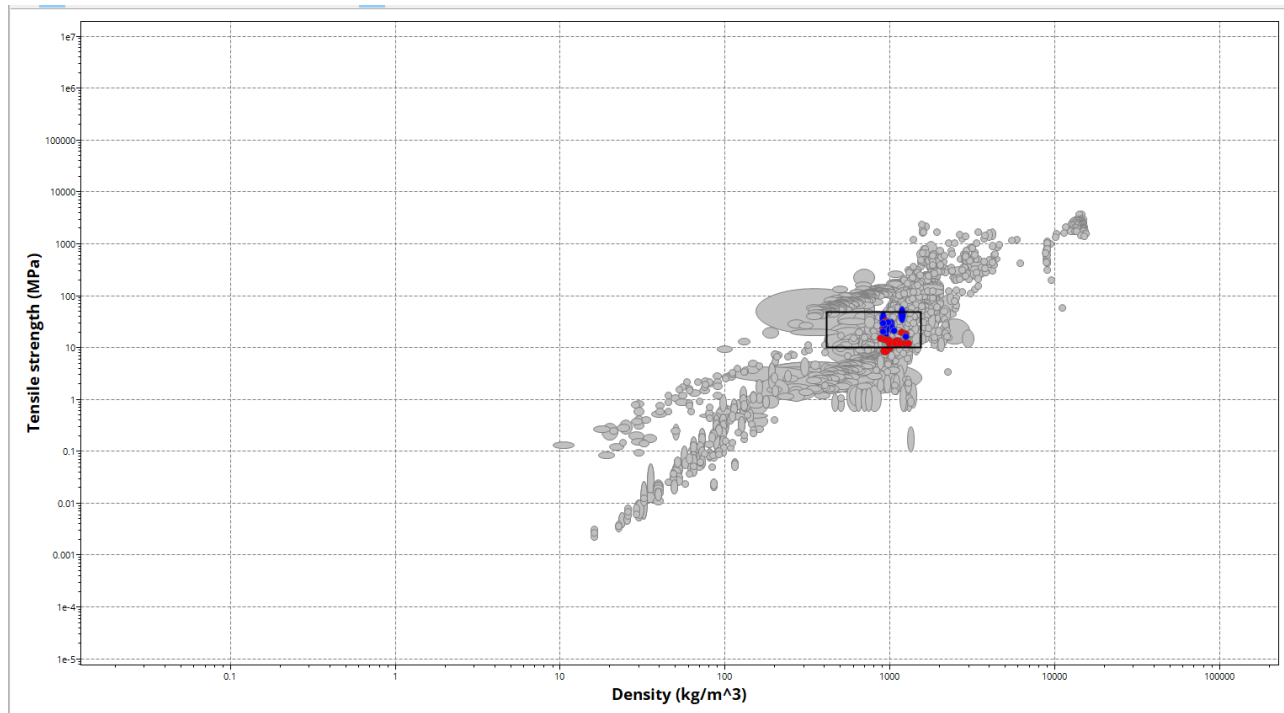


Figure 6: Ashby chart comparing density and tensile strength

Figure 6 shows the material selection criteria between approximately 10–50 MPa tensile strength and 700–2000 kg/m³ density. This was used to filter materials with sufficient tensile strength to maintain structural integrity during its cycle life whilst ensuring the mobile phone housing remained lightweight and comfortable to handle.

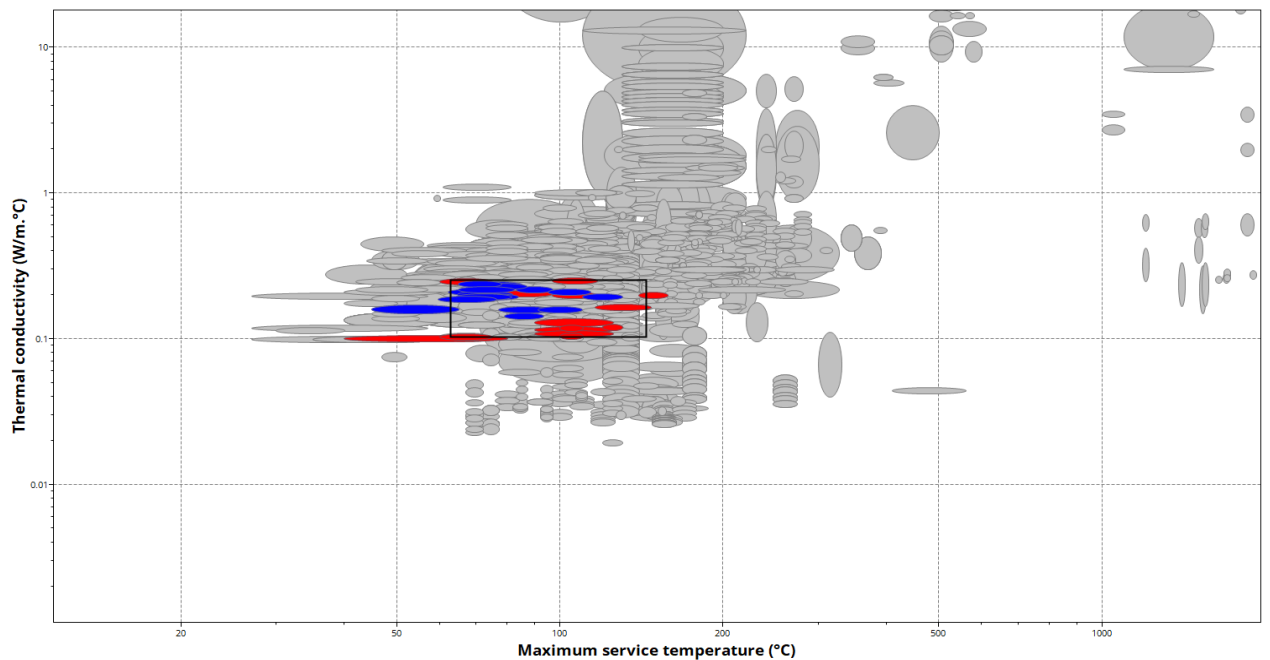


Figure 7: Ashby chart comparing thermal conductivity and maximum service temperature.

Figure 7 shows a selection of materials between 70-150°C maximum service temperature and a thermal conductivity of 0.1-0.30 W/m·°C. This ensured the remaining material could withstand temperatures during normal operating conditions whilst preventing a large build-up of heat transferring into the mobile phone housing causing discomfort to the customer.

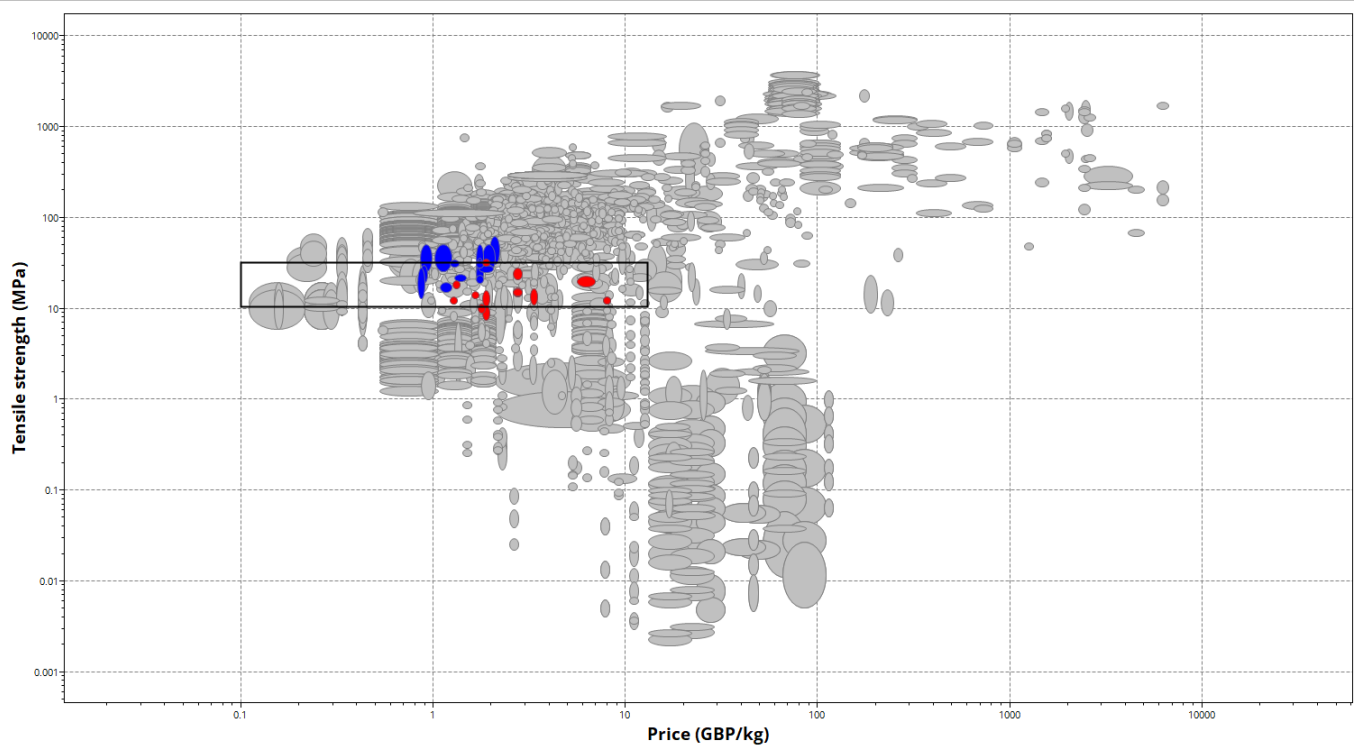


Figure 8: Ashby chart comparing tensile strength and price.

Figure 8 shows the material selection criteria of 10–50 MPa tensile strength against a price range of 0.1–10 GBP/kg. This allowed suitable materials to be identified that provided adequate structural strength for the mobile phone housing whilst remaining cost-effective for high-volume polymer injection moulding production.

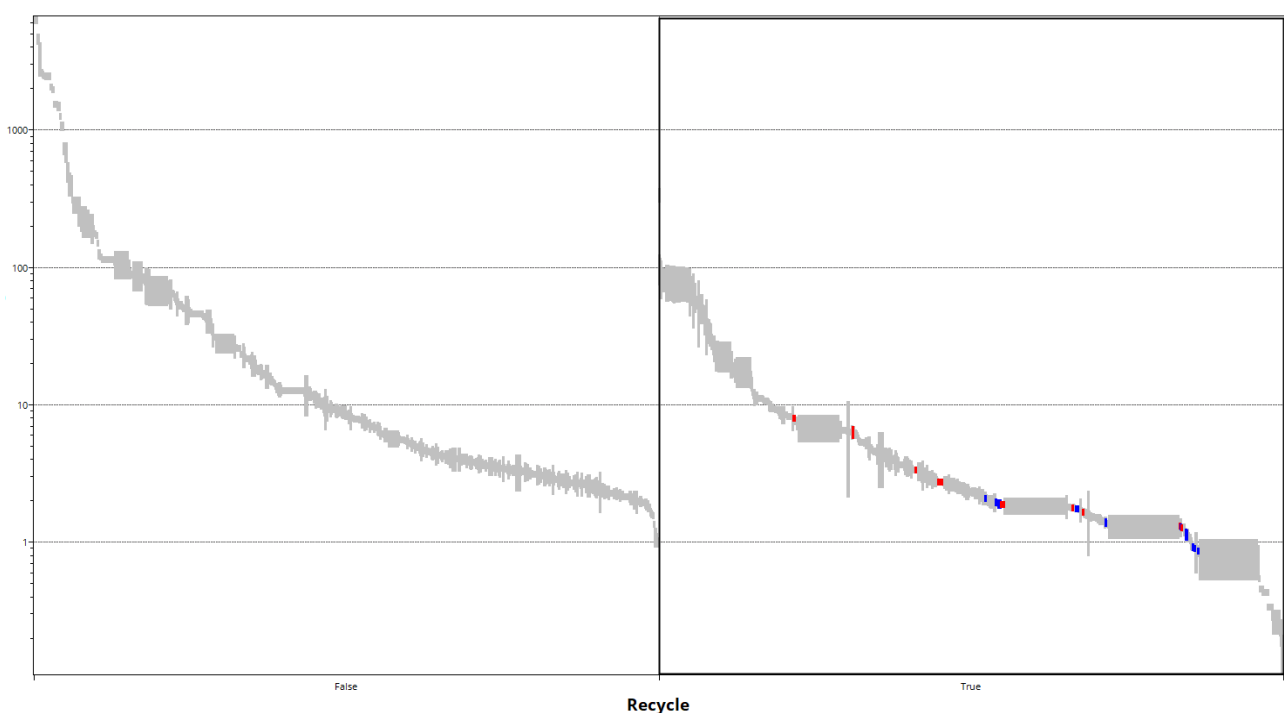


Figure 9: Ashby chart showing material recyclability.

Figure 9 outlines the remaining materials filtered through the material study and whether they can be recycled. This is an important criterion as materials that can be recycled at the end of their life cycle prevent increased waste ending up at landfill and contribute towards improved product sustainability.

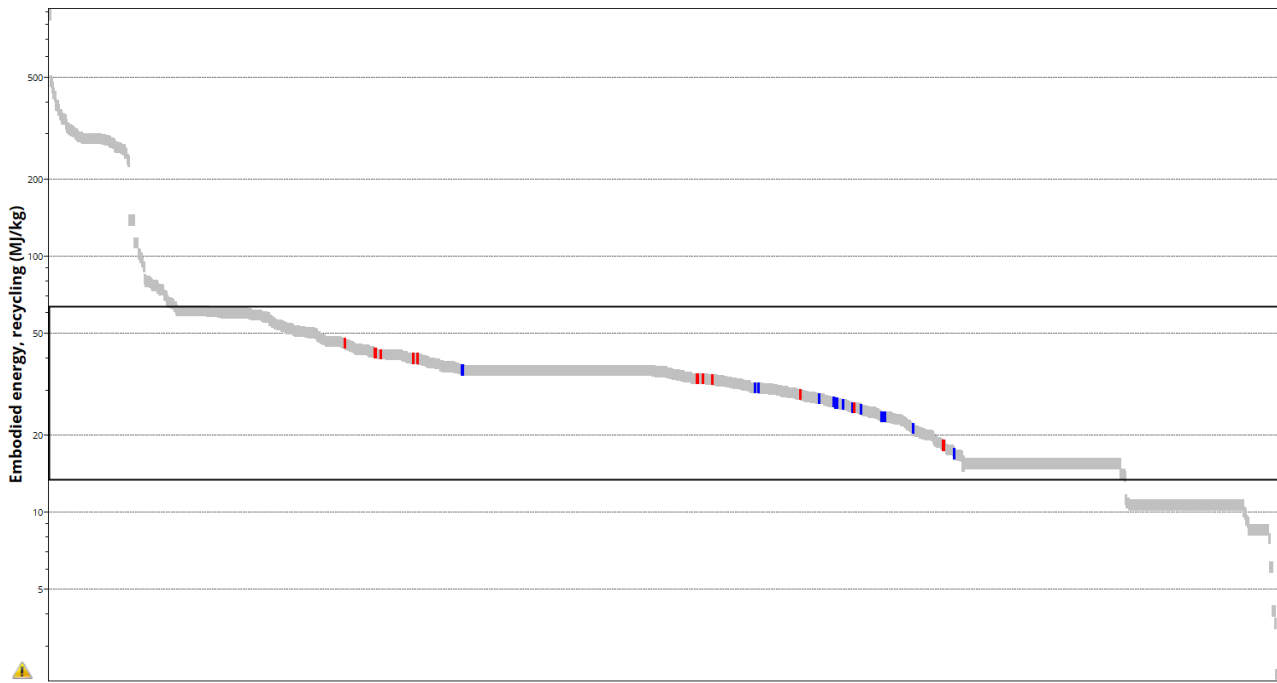


Figure 10: Ashby chart showing embodied energy of recyclable materials.

For further environmental consideration, Figure 10 highlights a selection of materials with a range of 15-60MJ/kg embodied energy. A lower range is more sustainable as embodied energy involves the total amount of energy required for material extraction, processing and transporting (University of Calgary, n.d.).

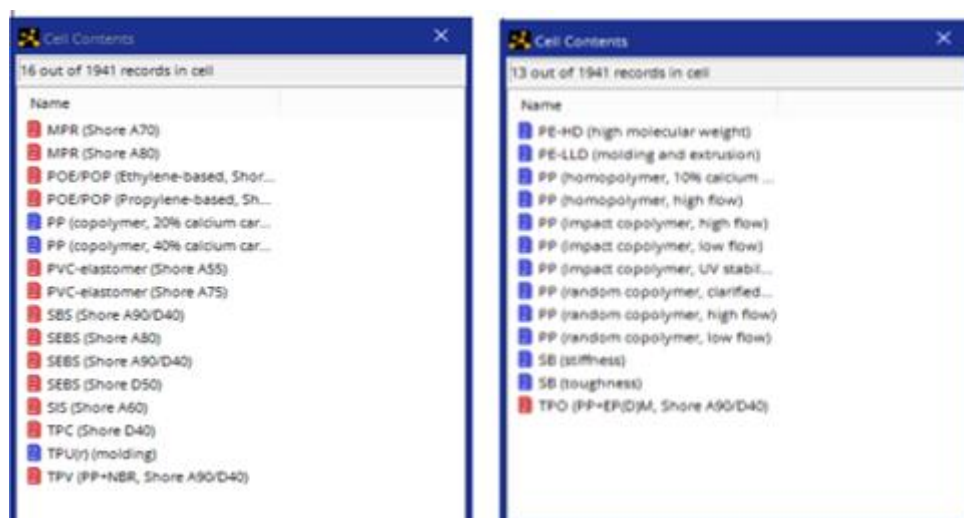


Figure 11: Granta Edu Pack material selection results showing acceptable and excellent materials for polymer injection moulding

Figure 11 shows the final material selection based on suitability for polymer injection moulding. Materials chosen were those only classified as acceptable and excellent to ensure they were compatible with high volume production requirements for the mobile phone housing. From the remaining candidate materials, TPO, Thermoplastic Polyurethane (TPU) and Thermoplastic Vulcanizate (TPV) were selected for further analysis as they satisfied all requirements of the material selection study and were considered suitable for the mobile phone housing product.

4.3.1 Final Material Comparison

The three chosen materials from Section 4.3 were analysed and compared against the chosen criteria in the material study and outlined in Table 5.

Table 5: Comparison of candidate material properties for the mobile phone housing (Source: Granta Edu Pack 2024).

Property	TPO (PP+EP(D)M)	TPU(r) (moulding)	TPV
Density (kg/m ³)	898	1180	980
Tensile Strength (MPa)	15.25	46.5	13.6
Young's Modulus (GPa)	0.207	1.69	0.008875
Elongation (%)	611.5	305	347.5
Max Service Temperature (°C)	149	71.5	125
Recyclable	Yes	Yes	Yes
Injection Moulding Suitability	Excellent	Acceptable	Acceptable
Price (GBP/kg)	2.75	2.08	3.325
Embodied Energy (MJ/kg)	32.75	50.2	41.3

The three candidate materials perform differently across the selected criteria, with each material offering advantages in specific areas. TPU demonstrated the highest tensile strength and young's modulus, providing the greatest stiffness and resistance to deformation compared to TPO and TPV. In addition, TPU was identified as the lowest-cost material, making it the most economical option for high-volume manufacturing. However, TPO achieved the best overall performance in elongation,

maximum service temperature, density, injection moulding suitability and embodied energy. These characteristics make TPO suitable for a lightweight mobile phone housing, providing adequate impact resistance whilst supporting high-volume manufacture. The excellent injection moulding rating achieved by TPO was particularly important as polymer injection moulding was selected as the manufacturing process for the final design.

TPV exhibited the lowest young's modulus value of 0.008875 GPa, indicating a significantly lower stiffness than both TPO and TPU. This raises concerns regarding its ability to maintain dimensional stability and structural integrity during everyday use. In addition, TPV was the most expensive material of the three candidates.

Although TPU demonstrated higher tensile strength and stiffness, TPO provided the best overall balance of properties for the mobile phone housing. Its lower density supports a lightweight design, whilst its high elongation allows the material to deform more before failure, which is beneficial for applications where impact resistance is required. Furthermore, TPO achieved the lowest embodied energy value of 32.75 MJ/kg, reducing the environmental impact associated with material production and recovery. Therefore, TPO was selected as the final material for the mobile phone housing design.

4.4 Mould Calculations

To ensure the design of the mobile phone housing is suitable for manufacturing via polymer injection moulding, multiple calculations were used for justification. This aligns with Le Hang and Chinh (2024), who found that important polymer injection moulding parameters, such as mould clamping force and injection flow, help engineers perform the calculations needed to choose the correct equipment.

4.4.1 CAD Model Properties

Autodesk Fusion 360 was used to determine the volume and mass properties of the CAD model, as shown in Figure 12.

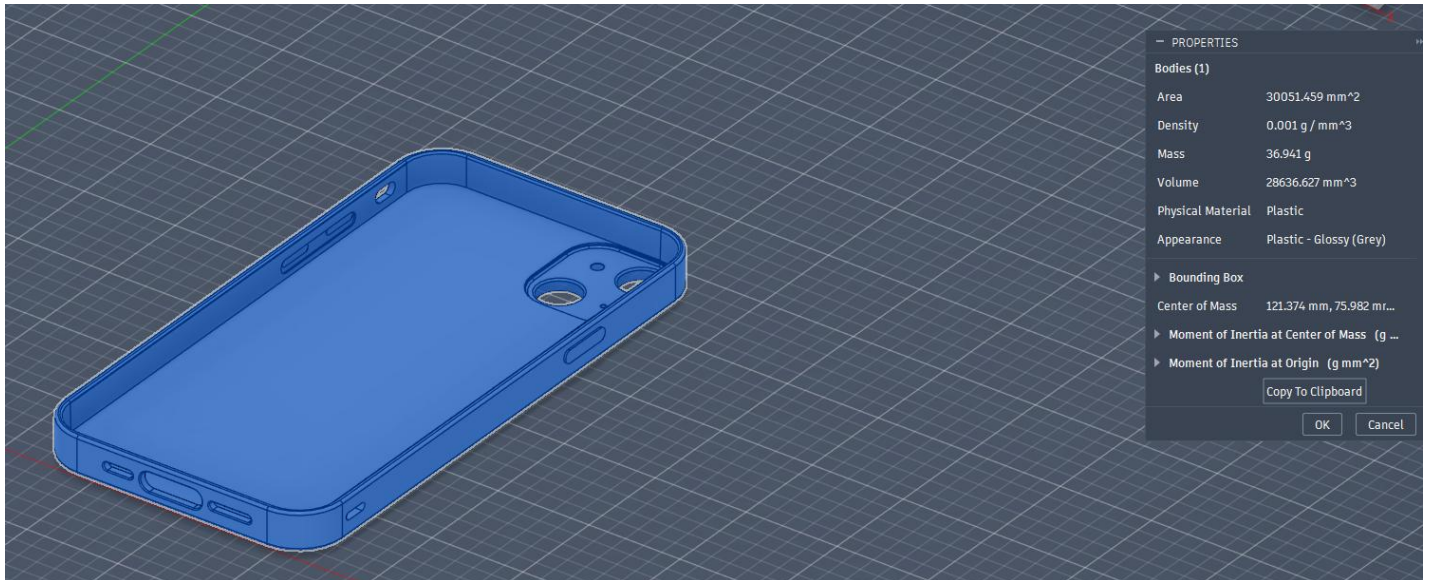


Figure 12: Volume and surface area properties of the mobile phone housing obtained from Autodesk Fusion 360.

Figure 12 shows a volume of 28636.627 mm³ (28.64 cm³) and an area of 30051.459 mm² (300.51 cm²). When used in conjunction with the density value of TPO outlined in Table 6, the volume allows for the mass of the mobile phone housing once manufactured.

Table 6: Calculation of the mobile phone housing mass using TPO density and CAD model volume.

Mass = Density x Volume
$898 \text{ kg/m}^3 \times 2.8637 \times 10^{-5} \text{ m}^3 = 0.0257 \text{ kg}$

Table 6 provides valuable data outlining the mass of the TPO mobile phone housing to be 0.0257kg (25.72g). This provides data that can be used in manufacturing and cost calculations as well as evidence that the selected material provides a lightweight design for customers.

4.4.2 Mould Clamping Calculations

Calculating the mould clamping force is essential as it allows the force required to keep the mould halves closed during polymer injection moulding to be determined (Keyence, n.d.). The required calculations can be seen in Table 7.

Table 7: Cavity Pressure Force Calculation

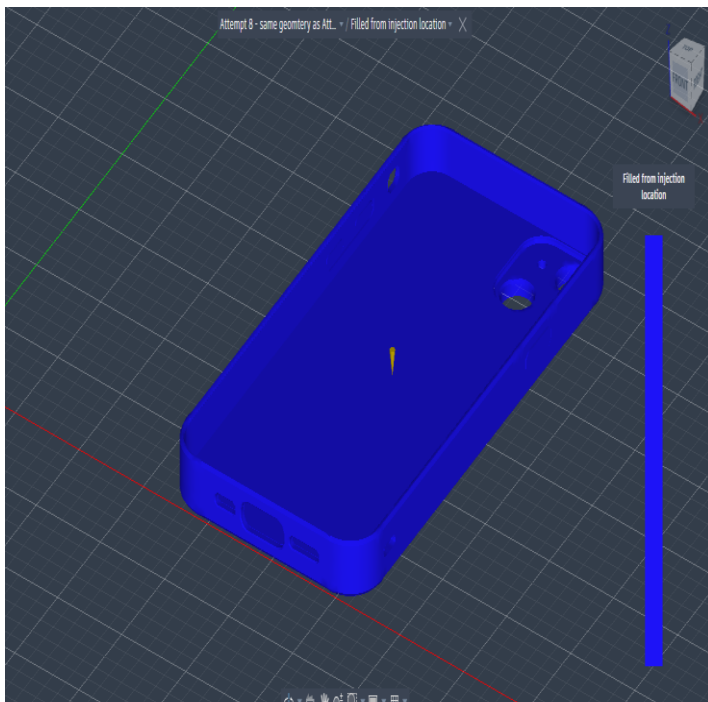
$F = \frac{pA}{1000} \text{ (Keyence, n.d.)}$	
P = Cavity Pressure (kgf/cm ²) A = Projected Area (cm ²)	
A = 15cm x 7.62cm	
A = 114.3 cm ²	
$F = \frac{500\text{kgf/cm}^2 \times 114.3\text{cm}^2}{1000}$	
F = 57.15 tonnes	

A required clamping force of 57.15 tonnes would be required to keep the mould halves closed during injection moulding. A cavity pressure of 500 kgf/cm² was selected based on recommended injection moulding pressure values for thermoplastic materials (Keyence, n.d.). This provides valuable data as a machine with a clamping force below 57.15 tonnes may result in mould separation during injection, leading to manufacturing defects.

5 Simulation and Validation

5.1 Plastics Simulation

The final CAD mobile phone housing design (Section 4.1) and the chosen polymer injection moulding parameters (Section 3.4.2) were simulated in Autodesk Fusion 360 plastics simulation to predict the final moulding characteristics of the mobile phone housing. Figure 13 outlines the results received during the simulation carried out.



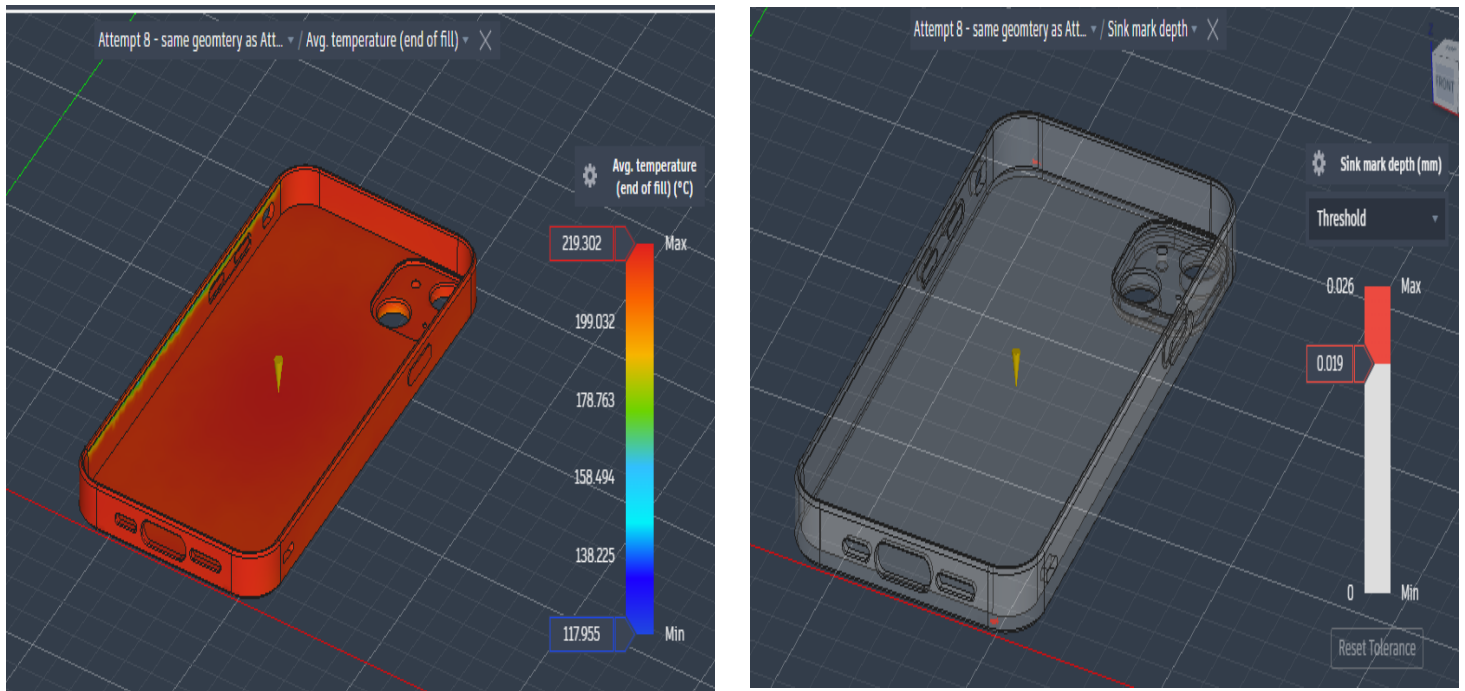


Figure 13: Final Autodesk Fusion 360 plastics simulation showing air traps, weld lines, sink marks, gate freeze and temperature distribution.

The fill time analysis indicated complete filling of the cavity with no evidence of short-shot defects. The weld line and air trap investigation highlighted the presence of weld lines primarily around the charging port openings and camera housing, as well as air traps located near the charging port openings. Despite this, these areas are not structurally critical areas where significant force during daily is unlikely to occur. The warpage analysis predicted a maximum deformation of 0.665 mm, whilst the sink mark analysis indicated minimal sink mark formation. Furthermore, the average temperature at the end of fill remained relatively uniform throughout the component, with some cooler areas identified near the securing strips located on the side walls for DFA purposes.

When evaluating the defects present in Figure 13, understanding the causes is vital. Weld lines occur when separate polymer flow fronts meet during cavity filling. Sink marks are caused by material shrinkage during cooling, whilst warpage occurs due to non-uniform cooling and shrinkage throughout the component (Gracija Nikolovska, 2022). To reduce the level of these defects in the final product, Section 3.4.3 provides evidence of multiple iterations for defect mitigation investigating geometry changes, temperature parameters and gate locations. The final simulation results

show that the chosen design can be manufactured successfully with defects limited to non-critical areas of the component.

5.2 Finite Element Structural Analysis

To assess the structural performance of the TPO mobile phone housing, FEA simulation was undertaken in Autodesk Fusion 360. Multiple iterations from 10 to 50 N were run to evaluate the strength of the mobile phone housing under a range of applied forces. The results of the 50 N simulation can be seen in Figure 14.

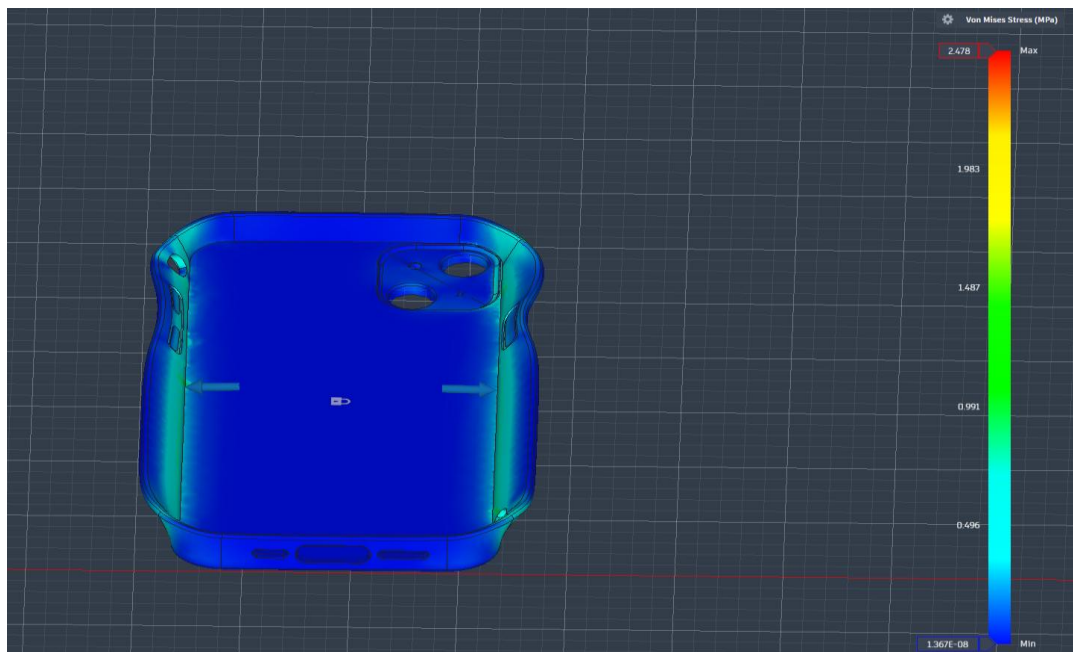


Figure 14: Von Mises stress distribution of the mobile phone housing under a 50 N loading condition

The highest stress concentrations occurred around the cut-outs of the mobile phone housing due to the reduction in material thickness within these areas. This can be attributed to the reduced wall thickness around these features when compared to the rest of the design. The multiple simulations of various factors were then compiled into Table 8 for further analysis and understanding of the product's performance.

Table 8: Summary of FEA results for loading conditions between 10 N and 50 N.

Load (N)	Max Von Mises Stress (MPa)	Minimum Safety Factor
10	0.496	115.397
20	0.991	57.698
30	1.487	38.466
40	1.983	28.849
50	2.478	23.079

According to SimScale (2023), a material will begin to yield if the calculated Von Mises stress reaches or exceeds its yield strength. When analysing the highest force applied to the TPO mobile phone housing, the maximum Von Mises stress was 2.478 MPa, with a minimum safety factor of 23.079. A safety factor is used to determine the difference between the strength of a component and the stress applied to it. Higher safety factor values indicate that the component can withstand a greater level of stress before failure occurs (Schenkelberg, 2014). The specified safety factor target within Autodesk Fusion 360 was set to 4.0. The minimum safety factor achieved was 23.079, indicating that the mobile phone housing remained well within the required limit under a 50 N load. A maximum load of 50 N was selected to simulate the upper range of forces that may be applied to the mobile phone housing during normal operating conditions.

6 Cost Calculation Analysis

6.1 Material Cost

A cost analysis of the required material for high volume polymer injection moulding provides an insight into the economic feasibility of the manufacturing production. Table 9 provides a cost breakdown of TPO material cost against the mobile phone housing design mass.

Table 9: Calculation of TPO material cost based on component mass and material price.

Material Cost = Mass x Price
0.0257kg x £2.75/kg
Material Cost = £0.0707

TPO provides a cost-effective raw material to product ratio for high volume polymer injection moulding. Assuming a production batch of 1000 mobile phone housings, the estimated raw material cost would be approximately £70.70. This highlights the relatively low material cost associated with manufacturing the TPO mobile phone housing.

6.2 Manufacturing Costs

Further cost analysis was undertaken to examine the manufacturing costs associated with the production of the TPO mobile phone housing. Table 10 outlines the manufacturing economics of the polymer injection moulding process, with the cost model input data summarised in Appendix A.

Table 10: Cost model used to determine the manufacturing cost per unit.

Cpc = Cm + CoTp + Ct
Cpc = Cost per piece, £/pc;
Cm = Starting material cost, £/pc;
Co = Cost rate of operating the work cell, £/min;
Tp = Average production time per piece, min/pc;
Ct = Cost of tooling if used in the unit operation, £/pc;
$Ct = \frac{\text{Tooling Cost}}{\text{Number of Parts before Replacement}}$
$Ct = \frac{10000}{500,000}$
Ct = £0.020 per part

$Co = CI + Ceq$
$CI = \frac{12.21}{60} \times (1 + 0.20)$
$CI = £0.244/\text{min}$
$Ceq = \frac{25500}{60 \times 1500 \times 10} \times (1 + 0.20)$
$Ceq = £0.034$
$Co = 0.244 + 0.034 = £0.278$
$Co \times Tp = 0.278 \times 0.333 = £0.093$
$Cpc = £0.0707 + 0.093 + 0.02$
$Cpc = £0.184$

Using the cost model, the manufacturing cost of the phone case was estimated at £0.184 per part. The operating cost of the work cell (£0.093) contributed the most to the final cost, followed by the material cost (£0.0707). Although the tooling cost was estimated at £10,000, when compared across 500,000 parts it only contributed to £0.02 per unit.

6.3 Break-Even Analysis

To understand whether high volume polymer injection moulding is suitable for the designed mobile phone housing, a break-even analysis provides information on required consumer sales to make profit. To carry out this study, a selling price for the mobile phone housing was set at £10.99 based on similar products on the market (Amazon, 2026). Table 11 outlines the calculations used to determine the break-even point.

Table 11: Break-even analysis for the TPO mobile phone housing.

Revenue = Total Cost
Selling Price x Qbe = Fixed Cost + Variable Cost per unit x Qbe
$Qbe = \frac{10000}{10.99 - 0.184}$
$Qbe = 926 \text{ mobile phone housings}$

The break-even analysis showed that 926 phone cases would need to be sold to recover the initial tooling cost of £10,000. Whilst injection moulding requires a high initial investment, the manufacturing cost per unit was estimated at only £0.184. As a result, the tooling cost can be recovered relatively quickly when producing at high volumes. This further supports the use of injection moulding for the manufacture of the mobile phone housing.

7 Sustainability Considerations

7.1 Material Recyclability

During the material selection study in Section 4.3, environmental considerations were built into the filter criteria. TPO was highlighted as being recyclable as well as having the lowest embodied energy (Section 4.3.1) out of the final selection, reducing the environmental impact associated with raw material extraction. As well as this, TPO at the end of its product life cycle can be reprocessed into new products, preventing waste being sent to landfill and further damage to the environment (Advanced Plastiform Inc., n.d.).

7.2 Energy Efficiency

To reduce energy consumption during manufacturing, the low density of TPO helped achieve a final CAD model mass of 25.7 g (Section 4.3.1), reducing the amount of material required for each component produced. A uniform wall thickness was also maintained throughout the design to avoid unnecessary material usage and improve manufacturability. Although the raised camera protection feature on the rear of the case increased the material usage slightly, it was considered necessary to provide adequate protection for the camera lenses.

7.3 Waste Reduction

To minimise waste during manufacturing, the mobile phone housing was designed as a single component rather than multiple separate parts. This reduces material usage and removes the need for additional assembly operations, helping to reduce overall manufacturing waste. Furthermore, in the event of excess material or part defects in polymer injection moulding, thermoplastics can be melted and remoulded repeatedly allowing the material to be transferred back into production (Tripaldi, 2024).

8 Discussion and Recommendations

8.1 Customer Requirement Analysis

To determine whether the final design was successful, the engineering characteristics assessed throughout the project were compared with the customer requirements identified in Section 3.1. Table 12 outlines the final mobile design against the performance attributes required.

Table 12: Comparison of final design performance against customer requirements.

Performance Requirements	Achieved?	Supporting Evidence
Impact Resistance	Yes	FEA simulation results showed that the phone case remained within acceptable stress limits under loads of up to 50 N.
Manufacturability	Yes	TPO chosen which is highly suitable for high volume polymer injection moulding
Lightweight	Yes	TPO chosen with a low density providing a lightweight design and a final weight of 25.7g
Durability	Yes	FEA results and the mechanical properties of TPO indicate that the design can withstand the expected loading conditions.
Surface Quality	Partially	DOE conducted to minimise surface defects, final process parameters produce the lowest variation in non-critical critical areas.
Component Fit	Yes	Maximum warpage result of 0.665mm which will not cause disruption to a phone being inserted
Cost Effective	Yes	Cost Analysis and Break-even analysis conducted and a final price per unit of £0.184

The final design of the mobile phone housing satisfied a majority of the customer requirements outlined within the project specification. However, surface quality was

only partially achieved due to defects such as weld lines and sink marks being observed during the final polymer injection moulding simulation. Although these defects occurred primarily in non-critical areas, further optimisation would be required to minimise their occurrence and improve alignment with the customer requirements.

8.2 Design Trade-Offs

When considering design trade-offs, the inclusion of the raised camera edge resulted in an increase in overall material usage, preventing a completely uniform wall thickness from being maintained. However, this feature was retained to provide additional protection to the camera lenses, reflecting features commonly found on existing phone cases available on the market and increasing the appeal of the final product.

As well as this, the initial tooling cost of £10,000 and machinery cost of £25,550 (Section 6.2) represent a significant upfront investment. However, polymer injection moulding was selected for the TPO mobile phone housing due to its suitability for high-volume manufacturing and its lower cost per unit at larger production volumes when compared to alternative processes such as 3D printing (Section 2.2).

8.3 Future Work

Further work for the TPO mobile phone housing would involve expanding the DOE study to further reduce the surface defects identified during the injection moulding simulation. In addition, the raised camera protection feature could be further optimised to reduce material usage whilst still providing adequate protection to the camera lenses.

9 Conclusion

The final mobile phone housing design was successfully developed for high-volume polymer injection moulding through material selection, alongside process simulations for manufacturing analysis. TPO was selected as the final material due to its low density, recyclability and suitability for injection moulding. The design was then developed and improved through CAD modelling, injection moulding simulation, DOE and FEA.

The final design achieved a mass of 25.7 g and was shown to withstand loads of up to 50 N. Injection moulding simulation confirmed that the component could be manufactured successfully, with visual defects and warpage reduced through the design optimisation process. The final manufacturing cost was estimated at £0.184 per unit, with a break-even point of 926 units.

The final design met the majority of the customer requirements whilst maintaining a balance between performance, manufacturability and cost. DFM and DFA principles were incorporated throughout the design process through the use of a single-part design, uniform wall thickness and a manufacturing process suitable for high-volume production.

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Appendix A – Cost Model Input Data

Table A1 provides the input data and sources used within the manufacturing cost model in Section 6.2.

Input Parameter	Value	Source
Tooling cost	£10,000	Rutland Plastics (2026)
Tool life	500,000 parts	Rutland Plastics (2026)
Hourly wage	£12.21/hr	Moore Kingston Smith (2025)
Labour overhead	20%	Innovate UK (2023)
Machine cost	£25,500	<u>Topstar</u> (2024)
Service life	10 years	<u>Topstar</u> (2024)
Production time	0.333 min/part	Zhang (2025)