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1 Abstract

This report evaluates material and manufacturing process selection for a plastic mobile phone protective case, mild steel vehicle outer body panels, and ceramic dinnerware. Mechanical and thermal properties, manufacturability, lifespan, cost, and sustainability are compared to justify material choices for high-volume production. This report considers alternative materials, and production methods.

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4 Introduction

The scope of this report is to analyse the materials and manufacturing methods used to produce three everyday products that are predominantly manufactured from a single material type.

- Plastic mobile phone protective cases
- Low carbon mild steel vehicle outer body panels
- Ceramic dinnerware.

The aim of this report is to provide an engineering justification for the selection of each material and its associated manufacturing process. This is achieved through a comparison of mechanical and thermal properties, manufacturability, cost, lifespan, and environmental considerations.

By evaluating each product against feasible alternative materials and processes, the report demonstrates how engineering material selection is driven by the requirement to balance performance, durability, and cost-effectiveness in high-volume manufacturing applications.

5 Literature Review

Materials science and engineering underpin material selection by linking material structure, properties, processing, and performance. Engineering materials are broadly classified into ceramics, polymers, metals, and composites.

Polymers offer lightweight, durable, and highly formable alternatives to natural materials and are commonly categorised as thermoplastics, thermosets, or elastomers. Thermoplastic Polyurethane (TPU) is widely used in consumer products due to its high impact resistance, elasticity, and suitability for injection moulding (*Brydson and Gilbert, 2016*).

Low-carbon mild steel consists primarily of iron with small additions of carbon, manganese, and silicon. Carbon contents of 0.05–0.25 wt% provide a balance of strength, ductility, formability, and weldability, making the material well suited to high-volume cold stamping in automotive applications (*Callister and Rethwisch, 2018*).

Ceramics exhibit high compressive strength, thermal stability, with resistance to wear and corrosion, but are inherently brittle (*Shackelford, 2008*). Their hardness, thermal resistance, and chemical inertness make them suitable for dinnerware, while processes such as RAM pressing enable efficient high-volume production (*Kingery, Bowen and Uhlmann, 1976*).

6 Selection and Description of Objects

6.1 Thermoplastic Polyurethane (TPU) Mobile Phone Protective Case

Most mobile phone protective cases are manufactured from a single polymer such as TPU, silicone, or polycarbonate. Injection moulding remains the dominant manufacturing process due to its ability to produce complex geometries at high production volumes with consistent quality (Podbase, 2025).



Figure 1 - (Case?, 2024)



Figure 2 - (Case?, 2024)

TPU offers a favourable combination of low density, high impact resistance, flexibility, and durability. These properties allow the material to absorb impact energy during drop events while maintaining sufficient stiffness to protect the device. In addition, TPU provides electrical insulation and low thermal conductivity, making it suitable for electronic device enclosures (F. Ashby, 2011). Relevant material considerations are summarised in Table 1.

Table 1 - Material Property Considerations

Considerations	Desirable Properties	
Mechanical Properties	• High Strength • High Impact Resistance	• High Formability • Low Density (Weight)
Thermal Properties	• High Thermal Stability/Heat Resistance	• Moderate Heat Dissipation Capability • Thermal Shock Resistance
Surface Properties	• High Surface Finish • High Corrosion Resistance	• High Scratch Resistance • High Friction Coefficient
Economical	• Material Cost • Cost Effectiveness (Tooling, Energy, Labour)	• Production Volume • Production Cycle Time. • Recyclability and Sustainability

6.2 Mild Steel Vehicle Outer Body Panels

Automotive outer body panels require a carefully balanced combination of mechanical strength, ductility, surface finish, and manufacturability to meet performance, safety, and aesthetic requirements (*Li et al., 2003*).



Figure 3 - (Tata Steel UK, 2020)



Figure 4 - (Lancefield, 2025)

Low-carbon mild steel remains one of the most widely used materials for this application due to its excellent formability, impact resistance, and relatively low cost. Its ductility enables complex panel geometries to be formed without fracture, while its strength provides resistance to denting and deformation in service. Additionally, mild steel is highly recyclable, contributing to its sustainability (*Granzow, 1990*). Material considerations are shown in Table 2.

Table 2 - Material Property Considerations

Considerations		Desirable Properties	
Mechanical Properties	• High Strength • High Impact Resistance	• High Formability • Low Density (Weight)	
Thermal Properties	• Low Coefficient of Thermal Expansion (CTE) • High Thermal Conductivity	• High Thermal Stability • High Temperature Strength (Weldability)	
Surface Properties	• High Surface Finish • High Corrosion Resistance	• Formability without defecting • Coatings for Protection and Aesthetics	
Economical	• Material Cost • Cost Effectiveness (Tooling, Energy, Labour)	• Production Volume • Production Cycle Time. • Recyclability and Sustainability	

6.3 Ceramic Dinnerware

Dinnerware products are manufactured from a range of ceramic materials, including porcelain, stoneware, earthenware, and bone china.



Figure 5 - Villeroy & Boch, 2025



Figure 6 - Denby, 2025

Stoneware ceramics are commonly used for dinnerware due to their high hardness, resistance to thermal shock, and ability to retain heat. (Pablo, 2007). Material property considerations are shown in Table 3.

Table 3 - Material Property Considerations

Considerations	Desirable Properties	
Mechanical Properties	• High Strength • High Chemical Resistance	• High Durability • Low Porosity (Hygiene)
Thermal Properties	• Thermal Stability • Thermal Shock Resistance	• Low Thermal Conductivity
Surface Properties	• Surface Finish • Scratch Resistance	• Wear Resistance • Aesthetic Versatility.
Economical	• Cost Effective (Tooling, Energy, Labour)	• Production Volume • Production Cycle Time.

7 Manufacturing Methods Comparison

TPU mobile phone cases are predominantly manufactured using injection moulding due to its short cycle times, high repeatability, and low unit cost at scale (Brydson and Gilbert, 2016). The process allows for precise control of wall thickness and surface finish, which is critical for both aesthetic and functional performance. Alternative methods are outlined in '[Appendix 1]'.

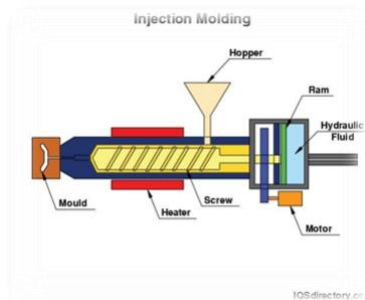


Figure 7 - (IQS Directory, 2026)



Figure 8 - (Lanson, 2025)

Cold stamping is the primary manufacturing method used for mild steel vehicle outer body panels due to its compatibility with high-volume production and excellent surface finish. The process avoids thermal oxidation, reducing post-processing requirements, while strain hardening during forming improves dent resistance (Li et al., 2003). Alternative processes are discussed in '[Appendix 2]'.



Figure 9 – Cold Stamping (Schwarzenberg, 2018).

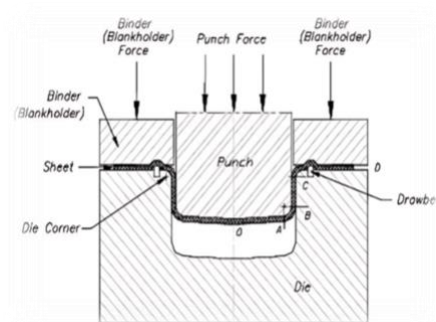


Figure 10 - Process (Jason, 2024)

Stoneware dinnerware is commonly manufactured using RAM pressing, which is well-suited to dense ceramic bodies and high-volume production. Compared with slip casting, RAM pressing offers shorter cycle times and improved dimensional consistency. Production rates of several thousand units per hour can be achieved, making the process highly cost-effective

for mass-market dinnerware (*Assel Darkhan et al., 2025*). Alternative methods are discussed in '[[Appendix 3](#)]'.



Figure 11 – Ceramic RAM press (SPN ENGINEERING AND CONSULTANT CO.,LTD, 2024)

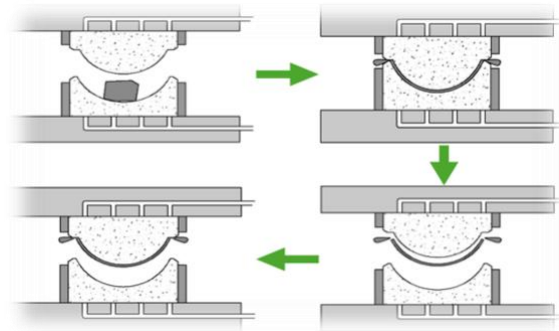


Figure 12 - RAM Pressing Process (ToolNotes, 2023)

8 Mechanical and Thermal Properties Comparison

8.1 Mechanical Properties

TPU exhibits moderate tensile strength but exceptionally high ductility and impact resistance, allowing it to absorb significant deformation without fracture. Typical elongation at break exceeds 50%, providing effective protection against drop and impact events (*SpecialChem, 2024*).

Low-carbon mild steel combines moderate ductility (20–30%) with significantly higher yield and tensile strength, enabling it to withstand both forming operations and in-service mechanical loads. This balance of properties makes it ideal for automotive outer panels. (*SSAB, 2025, Jiuzhou Metal Products Shandong Co., Ltd., 2026*).

Stoneware ceramics exhibit negligible ductility and low fracture toughness, as evidenced by their low tensile strength relative to compressive strength. However, their high hardness provides excellent wear resistance, which is advantageous in dinnerware applications (*Kingery, Bowen and Uhlmann, 1976, Pablo, 2007, Železný et al., 2023*). Mechanical properties are summarised in Table 4.

Table 4 - Mechanical Property Comparison

Mechanical Property	Thermoplastic Polyurethane (TPU)	Low Carbon Mild Steel	Stoneware Ceramic
Ductility (%)	53-55%	20-30%	<1%
Impact Resistance (KJ/m)	50-150	100-300	1-5
Strength (MPa)	42-42 (Tensile)	200-250 (Yield) 400-550 (Tensile)	300-600 (Compressive) 20-40 (Tensile)
Formability	Excellent – (Injection Moulding)	Excellent - (Cold Stamping)	Poor (Very Brittle)

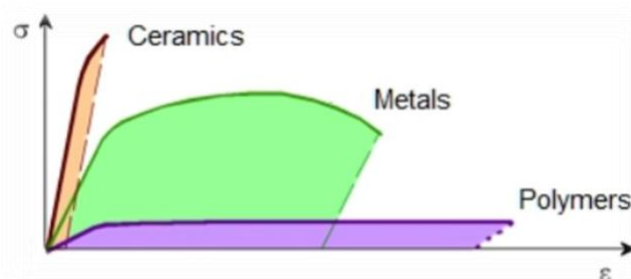


Figure 13 - Stress Train (Numerade, 2026)

8.2 Thermal Properties

TPU has a melting temperature in the range of 160–220 °C and softens at approximately 100–120 °C, enabling efficient processing via injection moulding. Its low thermal conductivity and high specific heat capacity provide effective thermal insulation for electronic devices (Callister and Rethwisch, 2018, SpecialChem, 2024).

Low-carbon mild steel has a melting temperature of approximately 1500–1540 °C and can operate at service temperatures up to 400–500 °C without significant loss of mechanical properties. Its moderate thermal conductivity provides a balance between heat dissipation and thermal insulation for vehicle occupants (Ssab, 2025).

Ceramics used in dinnerware exhibit high service temperatures (900–1200 °C), low thermal conductivity, and high specific heat capacity, enabling them to retain heat (Kingery, H Kent Bowen and Uhlmann, 1976). Thermal properties are summarised in Table 5.

Table 5 - Thermal Property Comparison

Thermal Property	Thermoplastic Polyurethane (TPU)	Low Carbon Mild Steel	Stoneware Ceramic
Melting Temperature (°C)	160 - 220	1500 - 1540	No Melting Point
Heat Resistance (°C)	100 - 120	400 - 500	900-1200
Specific Heat Capacity (Jkg ⁻¹ K ⁻¹)	1600 - 2100	470	800-500
Thermal Conductivity (Wm ⁻¹ K ⁻¹)	0.15 – 0.30	45 - 60	1.2 - 2.5

9 Lifespan and Cost Analysis

TPU mobile phone cases offer a favourable balance of durability, low material cost, and high-volume manufacturability. Although concerns exist regarding polymer waste and biodegradation this is negated with responsible manufacturing and global recycling processes. The combination of low cost and effective impact protection makes TPU a preferred choice (*Bhowmick and Stephens, 2001, Malíková et al., 2010*).

Table 6 - Biodegradation / Environmental Fate

Environment	Estimated Breakdown Time / Behaviour
Landfill	50 – 100+ years
Soil (natural conditions)	Very slow surface degradation only
Marine environment	Fragmentation → microplastics
Industrial composting	No degradation (unless specially formulated bio-TPU)

Table 7 - Life Span (In Use)

Factor	Typical Range
Functional lifespan	1 – 3 years
Cosmetic lifespan (yellowing, scuffs)	6 – 24 months
Shock-absorbing performance	Degrades gradually with UV, heat, oils

Untreated low-carbon mild steel exhibits limited corrosion resistance; however, protective treatments such as galvanising and painting significantly extend service life (*Farmer, 2020*). As shown in Table 9. When combined with low-energy cold stamping process and its strength, ductility, and recyclability, mild steel remains one of the most cost-effective materials for vehicle outer body panels.

Table 8 - Life cycle of Low Carbon Mild Steel

Condition	Typical Lifespan	Explanation / Corrosion Protection Mechanism
Untreated, unpainted	1 – 3 years (rapid corrosion)	Bare steel is directly exposed to oxygen and moisture, leading to rapid oxidation and rust formation.
Painted only	5 – 10 years	Paint provides a physical barrier, but once chipped or scratched, moisture reaches the steel and corrosion begins locally.
Galvanised (zinc-coated)	10 – 20 years	Zinc acts as a sacrificial anode, corroding preferentially to protect the underlying steel even when the coating is damaged.
Galvanised + paint (industry norm)	15 – 30+ years	Combines sacrificial protection from zinc with a barrier coating from paint, significantly slowing corrosion rates.
Modern OEM (e-coat + galvanising)	20 – 40 years	E-coat provides uniform coverage (including seams and cavities), while galvanising offers long-term sacrificial corrosion protection.

Ceramic dinnerware does not biodegrade but can remain functional for decades due to its hardness and thermal stability. Despite its brittleness, the low cost of raw materials and efficient manufacturing processes make ceramics a highly economical choice for dinnerware.

10 Material Selection and Alternative Choices

Alternative materials such as silicone, polycarbonate, metals, and composites are used in mobile phone cases. Silicone offers improved grip and shock absorption but is slower to manufacture and more difficult to recycle. Metal cases may interfere with signal transmission, while composites and leather provide limited impact resistance. TPU provides the most balanced combination of impact protection, manufacturability, recyclability, and cost.

Automotive body panels can be manufactured from aluminium or composite materials. While aluminium offers reduced weight, it is more expensive and requires higher-energy processing. Composite materials provide high strength-to-weight ratios but are costly, slow to manufacture, and difficult to recycle. Mild steel offers the best balance of strength, formability, surface finish, cost, and recyclability for high-volume production. (*Li et al., 2003*)

Although dinnerware can be manufactured from polymers, metals, or wood, ceramics provide superior thermal stability, wear resistance, and chemical inertness. Polymers lack thermal resistance, while metals exhibit high thermal conductivity, making them unsuitable for handling hot food. Ceramics offer the most appropriate balance of properties and cost for this application.

11 Conclusions

Material selection plays a critical role in determining product performance, durability, manufacturability, and cost. For each product analysed, the selected material represents a compromise between competing requirements rather than an optimisation of a single property.

TPU provides an effective balance of impact resistance, flexibility, and manufacturability for mobile phone protective cases. Mild steel offers an optimal combination of strength, ductility, surface finish, and recyclability for automotive body panels. Ceramics provide excellent thermal stability, hardness, and cost-effectiveness for dinnerware applications despite their inherent brittleness.

The manufacturing processes selected for each product reflect the need for high-volume, cost-effective production while maintaining required performance characteristics. Ultimately, effective engineering design requires balancing material properties and manufacturing constraints to achieve the most appropriate and economical solution.

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13 Appendices

13.1 Appendix 1

This comparison table was compiled by Mr Leighton Williams (UWTSD, January 2026) and summarises manufacturing processes commonly used for polymer products, including thermoplastic polyurethane (TPU). The table compares each process against product requirements, material properties, and economic considerations.

The analysis demonstrates that manufacturing method selection is strongly influenced by production volume, design complexity, and cost. While alternative processes may offer greater design freedom or suitability for lower volumes, injection moulding provides the most cost-effective solution for high-volume TPU components.

Table 9 - TPU Polymer Manufacturing Method Comparison

Manufacturing Process	Process Description	Advantages	Disadvantages
Injection Moulding	Heated polymer pellets are injected into a mould cavity under pressure, before cooling to solidify.	• High production speed – ideal for millions of parts with cycle times often in seconds. • High precision & quality – produces consistent parts with smooth surface finishes, high detail, and tight tolerances. • Low unit cost – very economical at high volumes (≈10,000+ units).	• High tooling cost – steel moulds are expensive, often costing thousands of pounds (£). • Long lead times – tooling can take weeks or months to produce. • Limited flexibility – design changes are costly once the mould is made.
Compression Moulding	Polymer pellets are compressed by a heated mould to form the shape of the part, before being cooled to solidify and ejected.	• Lower tooling cost – moulds are simpler and cheaper than injection moulds. • Ideal for medium/low volumes – cost-effective for smaller, specialised, or regional production runs. • Suitable for pliable materials – excellent for flexible materials.	• Slower cycle times – minutes per part compared to seconds for injection moulding. • Lower precision / higher waste – excess material often requires manual trimming. • Higher labour costs – less automation means more human intervention.
Additive Manufacturing (3D Printing)	3D printing using TPU filament, based on precision engineering drawings and a 3D printer.	• No tooling required – instant production, ideal for rapid prototyping or on-demand customised parts. • Design freedom – enables complex geometries, internal lattices, and customised texturing not possible with moulding. • Low waste – uses only the necessary amount of material.	• Slow production speed – not suitable for mass production; printing can take hours or days. • Higher per-unit cost – unit cost remains similar regardless of production volume. • Surface finish/material issues – visible layer lines; printed TPU can be less durable and more porous than moulded TPU.
Sources	(Minguella-Canela et al., 2019); (Chen & Hwang, 2012); (BigRep Industrial 3D Printers, 2025); (Mi et al., 2013); (Ngeow et al., 2024)		

13.2 Appendix 2

This comparison table was compiled by Mr Leighton Williams (UWTSD, January 2026) and reviews manufacturing processes commonly used for producing mild steel automotive vehicle outer body panels. The selection of manufacturing method is largely dictated by material composition, product requirements, and production volume.

Cold stamping is the dominant process due to its high production speed, low energy consumption, and compatibility with low-carbon mild steel. While hot stamping is a viable alternative, it requires boron-alloyed steels with different material properties and higher processing costs. As such, economic and performance considerations necessitate a compromise between achievable properties and manufacturing efficiency.

Table 10 - Low Carbon Mild Steel Manufacturing Method Comparison

Manufacturing Process	Process Description	Advantages	Disadvantages
Cold Stamping	Pressing cold sheet metal between a punch and die. Forming concaved and curved panels shaped through compression of the cold steel.	• High volume / speed – fastest cycle times, ideal for mass production. • Excellent surface finish – provides high-quality visible outer body panels. • Cost effective – low energy consumption and lower tooling costs than hot stamping. • Compatibility – widely used with standard mild steel and advanced high-strength steels.	• Springback – significant elastic recovery requiring complex tooling compensation. • Formability limits – lower ductility compared to hot stamping; complex or deep-drawn shapes are challenging. • Work hardening – increased hardness can lead to brittleness if overworked.
Hot Stamping (Press Hardening)	Steel sheet is heated to ~900 °C, formed between a punch and die, before being quenched to harden the steel with greater strength.	• Intricate shapes – high ductility at elevated temperatures allows complex, deep, or sharp-cornered shapes. • High strength / low weight – ultra-high-strength components enable thinner gauge steels. • No springback – rapid quenching freezes the shape, eliminating springback.	• Slower speed – lower production rates than cold stamping. • High cost & energy – extremely high energy consumption, specialised furnaces, cooling systems, and tooling. • Secondary processing – laser trimming and piercings required due to hardened material.
Roll Forming	A continuous process where steel sheet metal is fed through consecutive sets of rollers to form a final shape.	• High strength / low weight – gradual bending increases material strength and allows thinner gauge steels. • Long parts – ideal for producing long straight components. • Minimal waste – highly efficient material utilisation.	• Limited shape complexity – primarily suited to constant cross-section components. • Initial cost – higher upfront cost for multiple roller dies (offset in high-volume runs). • Inflexible lengths – harder to adjust part lengths once the line is set.
Hydroforming	Uses high-pressure hydraulic fluid to force metal into a die.	• Design freedom – allows complex, asymmetrical, or hollow structural shapes. • Part consolidation – replaces multiple stamped/welded parts with a single component, reducing assembly. • High surface quality – low metal-to-tool contact reduces surface damage. • Weight reduction – thicker steel only where required, reducing overall mass.	• Slow cycle times – slower than traditional stamping, limiting suitability for mass production. • High equipment cost – requires expensive pressurised machinery. • Limited to specialised parts – generally used for niche structural components, not full car bodies.
Tailor Welded Blanks (TWB) + Stamping	Two or more sheets (different thicknesses or grades) are laser welded together before stamping.	• Performance optimisation – improved structural and crash performance. • Reduced assemblies – eliminates the need for later welding of reinforcements.	• Higher initial cost – high cost of laser welding equipment and blanks. • Complex process control – requires precision control of weld line positioning during stamping. • Limited availability – relies on specialised suppliers for tailored blanks.
Sources	(Mori et al., 2017); (ScienceDirect, 2022); (Folkson and Sapsford, 2022); (ScienceDirect, 2015); (Kacar and Ozturk, 2014); (Bobade and Badgujar, 2017)		

13.3 Appendix 3

This comparison table was compiled by Mr Leighton Williams (UWTSD, January 2026) and examines manufacturing processes commonly used for ceramic dinnerware, with specific focus on stoneware materials. Ceramic selection is influenced by clay composition, oxide content, coarseness, and porosity, all of which affect processing and final properties.

The table evaluates manufacturing methods based on product geometry and production efficiency. Jiggering and jollying are cost-effective for flatware such as plates and bowls, while more complex, deep-profile items such as mugs and cups are better suited to RAM pressing or high-pressure casting. Due to the coarser nature of stoneware compared to porcelain, slip casting was not selected for this application.

Table 11 - Stoneware Ceramic Manufacturing Method Comparison

Manufacturing Process	Process Description	Advantages	Disadvantages
Slip Casting (Traditional)	Liquid clay slip is poured into porous plaster moulds, allowing water absorption to solidify the clay before excess slip is drained.	• Complexity – ideal for complex, organic, or intricate shapes (e.g. handles, pitchers, detailed plates). • Low initial investment – lower capital cost than automated pressing methods. • Flexibility – easily adapted for small-batch or high-end customised production.	• Low productivity – long cycle times (hours), dependent on absorption rates. • Labour intensive – requires manual casting, draining, and finishing. • Mould wear – plaster moulds have short lifespans (≈90–130 cycles) and break easily.
RAM Pressing / High-Pressure Casting	Hydraulic pressure presses plastic clay between two porous resin moulds. High-pressure casting uses porous resin moulds filled with liquid slip.	• High efficiency – faster cycles and up to ~600% higher output than traditional methods. • Consistency – excellent dimensional accuracy, uniform thickness, and strength with reduced rejects. • Surface quality – produces smooth surfaces with minimal finishing required.	• High initial cost – expensive machinery and die tooling required. • Complexity limitations – generally restricted to shapes that can be released from two-part moulds. • Setup time – requires specialised equipment and significant initial setup.
Isostatic Pressing	Dry ceramic powder is compacted in an elastomer mould using uniform pressure applied from all directions.	• Superior density – produces very uniform, high-density parts, reducing warping during firing. • Dimensional accuracy – high consistency and ability to hold tight tolerances. • Shape versatility – capable of large, complex, and thin-walled components.	• High cost – expensive equipment and high technical requirements. • Lower rate – typically slower production rates than extrusion or conventional pressing. • Material waste – often near-net-shape, requiring high-quality spray-dried powders.
Jiggering / Jollying	A semi-automatic process where a piece of plastic clay is placed on a rotating mould and shaped by a forming tool (jigger for plates; jolly for hollow ware).	• High speed – very efficient for high-volume production of simple, round shapes. • Low cost – cheaper than press methods; uses inexpensive, replaceable moulds. • Flatness – excellent for producing large flat surfaces (plates, platters).	• Shape limitations – restricted to circular or symmetrical shapes. • Higher rejects – generally lower density than pressing, increasing risk of warping. • Mould wear – plaster moulds wear quickly and require frequent replacement.
Sources	(Hart, 1990, pp. 323–327); (Železný et al., 2023); (Bose et al., 2024); (Assel Darkhan et al., 2025)		