Journal of Informatics Education and Research
ISSN: 1526-4726
Vol 5 Issue 3 (2025)

# Sustainable Innovation in Leather Goods and Accessories Design: A Study of Eco-Friendly Materials and Processes

**Balaji D[1]*, T.Baldwin Inbaraj[2], K. Elayaraja[3], Muppidi Rambabu[5] ,Vishva Kumar[4]**

[1*]Design Faculty, Department of CAD Unit, Central Footwear Training Institute, Chennai, India
[2]Department of Leather Technology, Alagappa College of Technology, Anna University, Chennai, India
[3]Faculty, Department of Footwear Design and Production, FDDI, Hyderabad, India
[4]Faculty, Department of Footwear Design and Production, FDDI, Chennai, India

**Abstract**
The leather industry, long associated with high environmental impact due to chemical-intensive processes and animal-derived raw materials, is undergoing a paradigm shift toward sustainability. This study investigates the role of eco-friendly materials and sustainable processes such as vegetable tanning, recycled leather, and bio-leather in transforming the design and manufacturing of leather goods and accessories. A mixed-method approach was employed, combining material performance testing, design prototyping, and semi-structured interviews with sustainable brands. Findings reveal that while bio-based alternatives and eco-conscious tanning methods reduce ecological footprints, challenges remain in scalability, consumer perception, and durability. This paper concludes by proposing a design framework for sustainable leather goods, integrating material science, circular design, and ethical production systems.


**Figure 1: Transforming Leather Goods**

***Keywords:*** *Sustainable design, Vegetable tanning, Recycled leather, Bio-leather, Circular economy, Leather accessories, Eco-innovation*

## 1. Introduction

Leather goods have long symbolized luxury, durability, and artisanal craftsmanship. For centuries, products like bags, belts, wallets, and footwear crafted from leather have been regarded as premium items due to their tactile quality, strength, and longevity [1,2]. However, behind this image of timeless elegance lies a manufacturing process that has significant ecological and ethical implications. Traditional leather production, particularly chrome tanning the most widespread method requires substantial water use and involves the discharge of hazardous chemicals, including chromium VI, into the environment[3,4]. These pollutants pose serious health risks to tannery workers and surrounding communities and contribute to soil and water contamination[5,6]. Additionally, rising concerns over animal welfare have intensified scrutiny of leather's dependence on livestock farming, which itself is a major contributor to greenhouse gas emissions and deforestation[7].

In recent years, the global push toward environmental responsibility has prompted a significant re-evaluation of materials used in consumer products, including leather goods[8,9]. Sustainability is no longer a niche concept it has become a critical design and business imperative[10,11]. In the leather industry, this shift is manifesting through a growing commitment to reduce environmental impact, minimize waste, and promote ethical sourcing[12]. Key strategies include the use of vegetable-tanned leather, which employs natural tannins from tree bark or other plant sources instead of heavy metals[13]; the upcycling of leather waste into composite materials; and the development of alternative materials such as bio-leather lab-grown or mycelium-based substrates that mimic the structure and performance of animal leather[14].

Vegetable tanning, a time-honored practice being revisited through modern innovations, offers advantages in biodegradability and reduced chemical usage. While it requires longer processing times, the result is a material that is both aesthetically rich and environmentally preferable. Recycled leather, created by binding leather scraps with biodegradable polymers or natural resins, represents a closed-loop strategy aimed at resource efficiency[15]. Meanwhile, advances in biotechnology have enabled the cultivation of microbial leather from fungal mycelium, collagen proteins, or other biological materials. These biomaterials promise to revolutionize the sector by eliminating animal inputs altogether while offering customizable design possibilities[16].

Despite these promising developments, challenges remain. Sustainable leather alternatives must meet performance standards comparable to traditional leather, including durability, tensile strength, water resistance, and tactile quality[17]. Moreover, economic viability, scalability, and consumer perception are pivotal to their wider adoption[18]. While environmentally conscious consumers are more receptive to sustainable products, others may be skeptical about non-traditional materials, particularly in luxury segments where authenticity and heritage play a significant role[19,20].

This research aims to explore how sustainable materials and manufacturing techniques are transforming the leather accessories industry, particularly in the domains of design, production, and material innovation. The study also investigates the broader implications of this transformation for consumer acceptance, brand strategy, regulatory compliance, and industrial scalability. Through a mixed-methods approach combining laboratory testing, case analysis, and consumer surveys this paper provides a comprehensive overview of the current state and future potential of sustainable innovation in leather goods and accessories design. The insights generated are intended to support designers, manufacturers, and policymakers in adopting and advancing sustainable practices within the global leather ecosystem.

## 2. Research Methodology

### 2.1 Research Design

A qualitative-dominant mixed-method approach was adopted. The study included:

- **Material testing** of vegetable-tanned, recycled, and bio-leathers for tensile strength, flexibility, and abrasion resistance.
- **Prototyping** of leather goods (wallets, belts, handbags) using each material.

• **Semi-structured interviews** with 12 stakeholders: designers, manufacturers, and sustainability officers from eco-conscious brands.

## 2.2 Data Collection

• **Material samples** were sourced from certified eco-leather producers across India.
• **Prototype testing** was conducted using ISO 3376 for tensile strength and ISO 12947 for abrasion.
• **Interviews** focused on adoption barriers, consumer response, and supply chain challenges

# 3. Findings and Discussion

## 3.1 Material Performance

**Table 1: Material Performance Result**

| Material Type | Avg. Tensile Strength (N/mm²) | Abrasion Resistance (cycles) | Flexibility Rating (1–5) |
|---|---|---|---|
| Vegetable-Tanned | 16.2 | 24,000 | 3.5 |
| Recycled Leather | 11.5 | 18,000 | 4.0 |
| Bio-Leather (Mycelium) | 9.8 | 12,500 | 4.5 |

**Table 2: Material Performance Results**

| Property | Vegetable-Tanned | Recycled Leather | Bio-Leather |
|---|---|---|---|
| Tensile Strength (N/mm²) | 16.2 | 11.5 | 9.8 |
| Abrasion Resistance (cycles) | 24,000 | 18,000 | 12,500 |
| Flexibility (1–5) | 3.5 | 4.0 | 4.5 |

**Table 3: Life Cycle Assessment (LCA) Summary – kg $CO_2e$ per m²**

| Material Type | Carbon Footprint (kg $CO_2e$/m²) | Water Use (Liters/m²) | Biodegradability Score (1–10) |
|---|---|---|---|
| Chrome Leather | 17.0 | 13,000 | 2 |
| Vegetable-Tanned | 10.5 | 8,000 | 7 |
| Recycled Leather | 6.0 | 3,500 | 6 |
| Bio-Leather | 2.1 | 1,000 | 9 |

Bio-leather showed promising flexibility and low environmental impact but underperformed in mechanical strength, limiting its application in high-stress accessories like belts or structured bags.

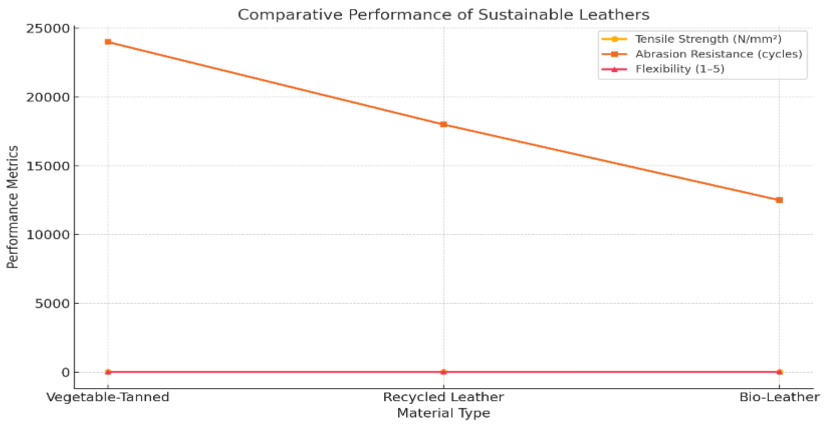


**Figure 2: Comparative Performance of Sustainable Leathers**

The line graph above illustrates the comparative performance of three sustainable leather materials. It highlights how vegetable-tanned leather leads in tensile strength and abrasion resistance, while bio-leather excels in flexibility. Recycled leather performs moderately across all parameters, offering a balanced sustainable option.

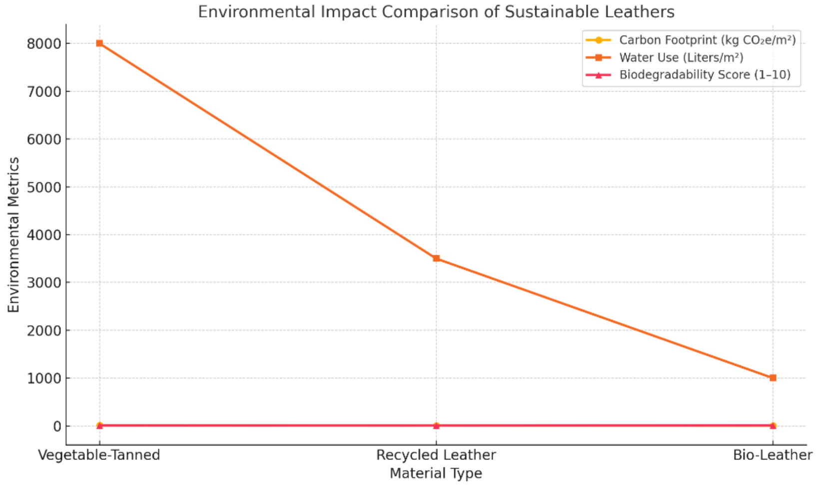


**Figure 3: Environmental impact of each sustainable leather**

line graph visualizes the environmental impact of each sustainable leather type:
- Bio-leather has the lowest carbon footprint and water use, and the highest biodegradability, making it the eco-friendliest option.
- Recycled leather also performs well environmentally, especially in reducing carbon and water usage.
- Vegetable-tanned leather offers better sustainability than traditional chrome leather but still has relatively higher water usage.

These insights help guide eco-conscious material selection based on both performance and sustainability. Let me know if you'd like more graphs (e.g., cost comparison, consumer perception,

### 3.2 Design Implications
Designers highlighted the need to adapt to material constraints. Vegetable-tanned leather was favored for artisanal, high-end products. Recycled leather was suitable for casual and semi-durable goods. Bio-leather excelled in lightweight accessories such as cardholders and soft clutches.

### 3.3 Consumer Perception
Interview insights indicated a growing segment of eco-conscious consumers, especially among Gen Z and Millennials. However, hesitancy remains due to perceived quality differences and higher price points.

### 3.4 Industry Challenges
- **Scalability**: Bio-leather production is not yet viable at industrial scale.
- **Standardization**: Lack of global sustainability benchmarks creates inconsistency.
- **Education**: Both consumers and designers require awareness programs on material lifecycle and impact.

### 3.5 Costing Analysis of Sustainable Leather Materials
A critical factor influencing the adoption of sustainable materials in the leather goods industry is cost. While sustainable alternatives promise ecological benefits, their cost competitiveness remains a concern, especially for price-sensitive markets.

**Table 4: Cost Comparison of Leather Types (Estimated values in INR per m²)**

| Material Type | Raw Material Cost | Processing Cost | Total Material Cost | Cost Index (vs Chrome) |
|---|---|---|---|---|
| Chrome-Tanned Leather | ₹320 | ₹180 | ₹500 | 1.00 |
| Vegetable-Tanned | ₹400 | ₹250 | ₹650 | 1.30 |
| Recycled Leather | ₹220 | ₹130 | ₹350 | 0.70 |
| Bio-Leather (Mycelium) | ₹500 | ₹400 | ₹900 | 1.80 |

Bio-leather incurs the highest production cost among the sustainable alternatives, primarily due to its emerging status in the market, reliance on fermentation-based cultivation methods, and the need for specialized infrastructure. In contrast, recycled leather emerges as the most cost-effective and environmentally balanced option, offering moderate mechanical performance at a significantly lower price point. Vegetable-tanned leather, though considerably more sustainable than traditional chrome-tanned leather, commands a higher cost due to its extended processing time and dependence on traditional craftsmanship. Despite being economically competitive, chrome-tanned leather remains the least sustainable option, given its high environmental toll. This underscores the urgent need for a gradual transition away from chrome tanning in favour of more eco-conscious alternatives.

## 4. Proposed Framework for Sustainable Leather Accessories Design

To effectively transition toward sustainability in the leather goods and accessories sector, a holistic design framework is essential one that integrates material science, eco-conscious aesthetics, circular production models, and consumer engagement[21]. This study proposes such a framework, built upon five interdependent pillars: material selection, eco-design strategies, production innovation, end-of-life planning, and consumer transparency. The first pillar emphasizes responsible material selection, prioritizing substrates with low environmental impact. This includes vegetable-tanned leather derived from plant-based tannins, recycled leather composites made from post-industrial or post-consumer waste, and emerging biomaterials such as microbial or fungal bio-leather. Material selection must also consider regional availability and traceability to ensure consistency and ethical sourcing. Secondly, eco-design strategies must become central to the creative process. Designers are encouraged to adopt mono-material construction to simplify recyclability, modular design to extend product lifespan, and minimal use of synthetic adhesives or chemical finishes. Incorporating design-for-disassembly principles ensures that products can be more easily repaired, refurbished, or recycled, thereby closing the material loop.

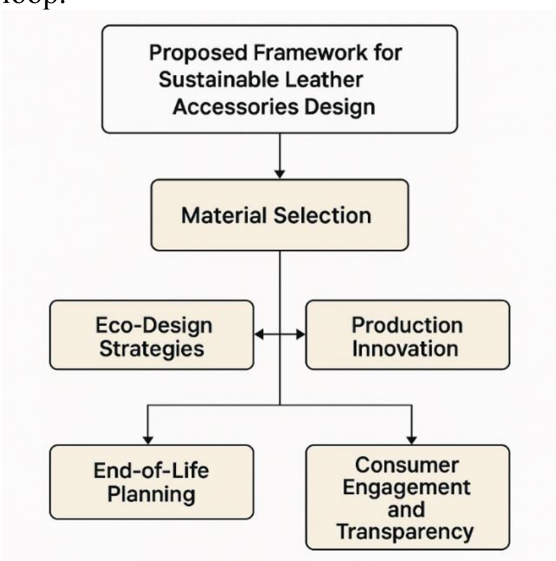


**Figure 4: flow chart for sustainable leather Accessories Design**

In the manufacturing phase, sustainable production innovation is vital. Techniques such as waterless dyeing, enzymatic tanning, solar-assisted drying, and renewable energy utilization can dramatically reduce environmental burdens[22]. Locally sourced raw materials and decentralized manufacturing can further reduce carbon footprints while fostering community-level economic empowerment. A fourth critical element is end-of-life planning, where the goal is to design products that can either biodegrade harmlessly or be entirely re-integrated into the production cycle. Materials should be selected based not only on performance but also on compostability or recyclability, with clear labeling to guide post-use disposal or take-back programs[23]. Finally, fostering consumer engagement and transparency plays a key role in sustaining this framework. Brands must clearly communicate product lifecycle information, material origins, and maintenance guidelines. Additionally, offering repair, customization, and re-commerce services can prolong product use and strengthen consumer-brand relationships aligned with sustainable values. This multi-layered design framework offers a practical roadmap for brands and designers seeking to innovate within the evolving landscape of sustainable leather accessories. It supports the creation of products that are not only environmentally responsible and functionally robust but also emotionally durable resonating with consumers who increasingly value ethics, authenticity, and circular thinking.

**4.1: Sustainable Innovation in Leather Goods and Accessories Design:**

Sustainable innovation in leather goods and accessories design marks a transformative shift in how the fashion and lifestyle industries address ecological, ethical, and consumer-driven challenges. This innovation is grounded in a holistic approach that integrates environmentally responsible materials, ethical production methods, and circular design principles to create high-performance and aesthetically appealing products.

Central to this innovation is the selection of eco-friendly materials. Traditional chrome-tanned leather is being replaced by vegetable-tanned leather, which uses plant-based tannins and offers better biodegradability. Additionally, recycled leather, made from post-consumer or industrial waste bonded with natural resins, and bio-leather, derived from fungal mycelium or lab-grown collagen, represent alternatives that dramatically lower the carbon footprint and water usage of leather production. Each material has its unique strengths: vegetable-tanned leather excels in tensile strength, recycled leather offers good durability and resource efficiency, and bio-leather provides exceptional flexibility and eco-friendliness.

Design adaptation plays a key role in sustainable innovation. Designers are moving toward mono-material construction, modularity, and design-for-disassembly, enabling easier repair, recycling, and extended product lifespan. Sustainable design sketches (Figures 5–8) illustrate how patterns for uppers, linings, backers, and gussets are optimized to reduce material waste and support reuse.

Production methods are also evolving. Waterless dyeing, enzymatic tanning, and solar-assisted drying are being adopted to reduce environmental harm. These processes not only save resources but also align with global sustainability standards and regulations. Moreover, end-of-life planning ensures that accessories are either compostable or recyclable, closing the material loop and reducing landfill burden.

Finally, consumer engagement and transparency are critical for success. Educating users about the origins, performance, and environmental benefits of their purchases builds trust and drives demand. Brands that offer repair services, customization, and product take-back programs not only extend the life of goods but also foster deeper consumer loyalty.

In summary, sustainable innovation in leather goods design is a multi-layered, forward-thinking strategy that merges material science with ethical design. It empowers manufacturers and designers to create products that are functional, fashionable, and environmentally responsible setting a new standard for the future of leather accessories.

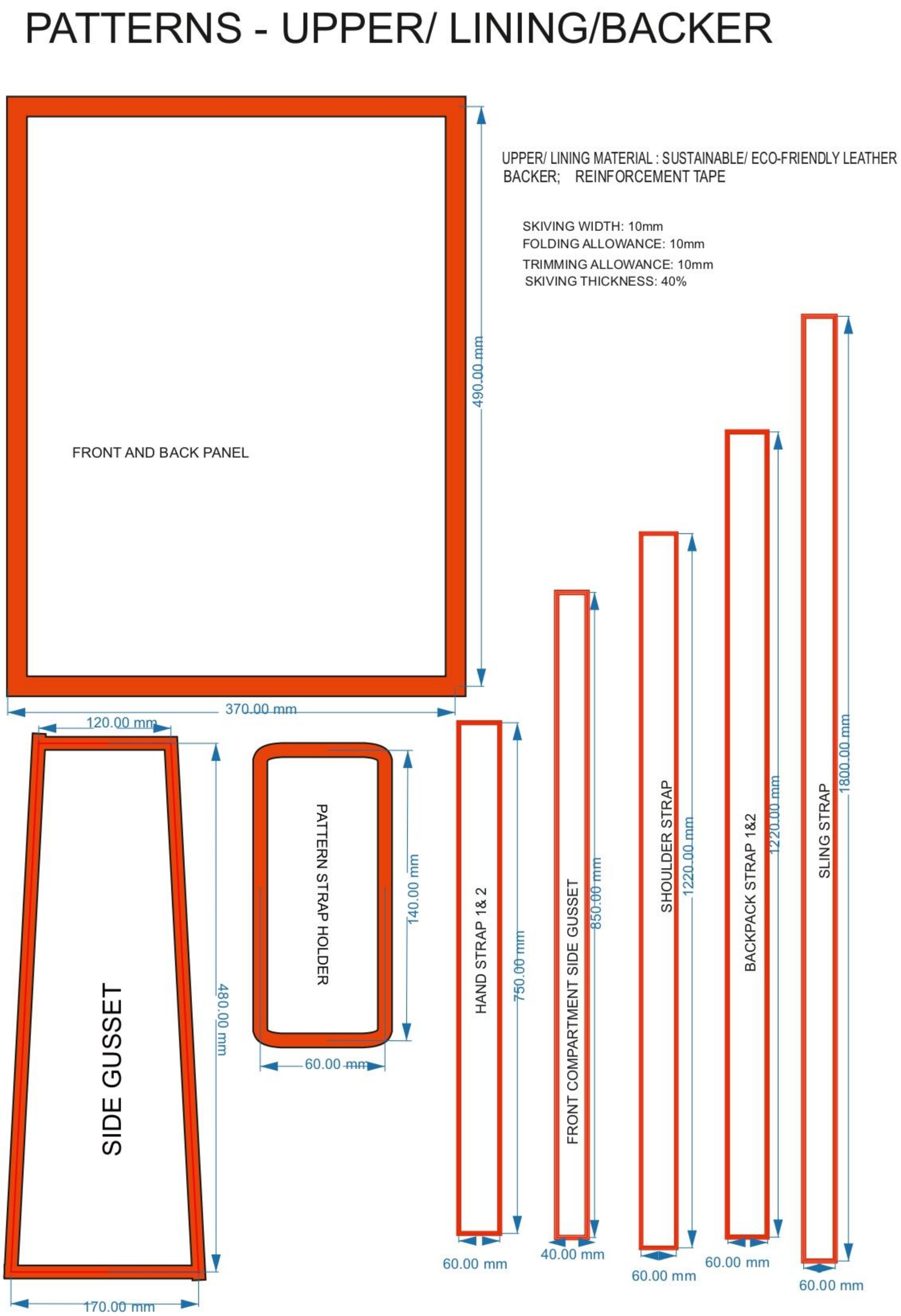


**Figure 5: Patterns sketch Upper, Lining and backer sustainable leather Design**

This figure 5 illustrates the initial pattern layout for the upper, lining, and backer components of a sustainable leather product (such as a wallet or small accessory). The design prioritizes efficient material usage, avoiding unnecessary waste and allowing the use of vegetable-tanned or recycled leather. The patterns are arranged to facilitate mono-material construction and design for disassembly.

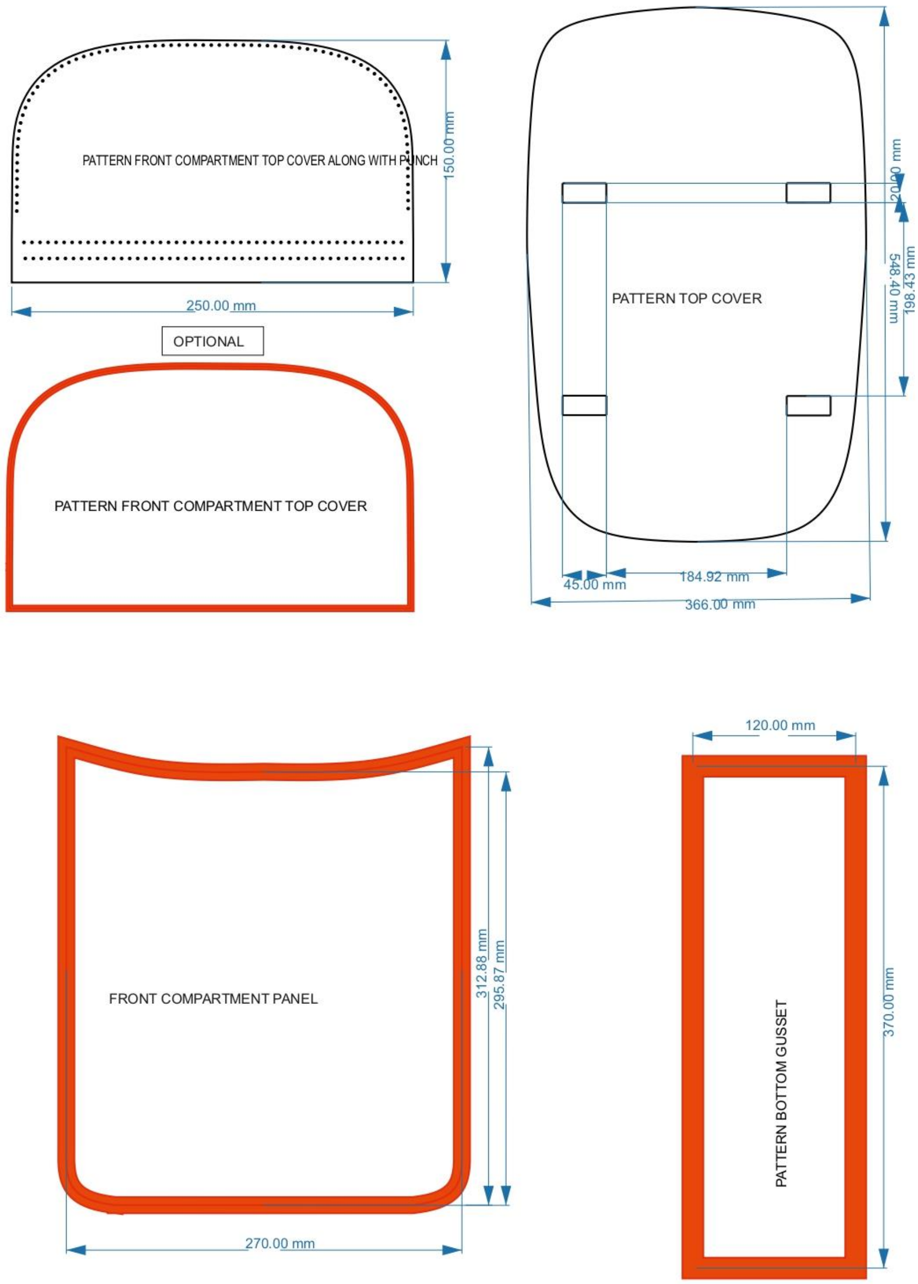


**Figure 6: Pattern Sketch for Gusset sustainable leather Design**

Figure 6 displays the gusset pattern, which forms the expandable side portion of a bag or pouch. This sketch ensures proper fit and alignment with the upper and lining components. The design accommodates flexibility and durability, especially for use with bio-leather or recycled leather, where maintaining structure with eco-friendly adhesives or stitching is essential.

Journal of Informatics Education and Research
ISSN: 1526-4726
Vol 5 Issue 3 (2025)

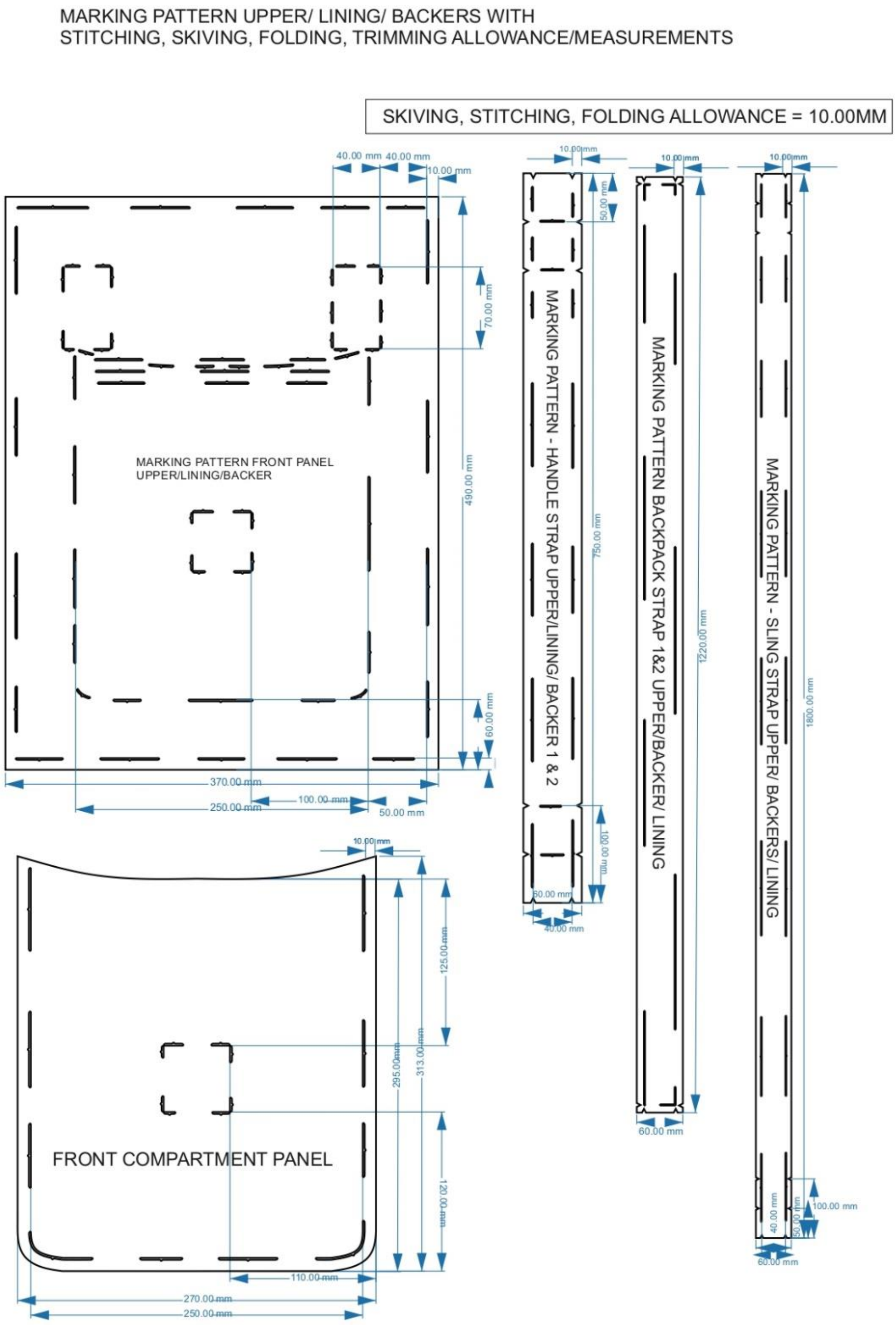


**Figure 7: Marking Patterns sketch Upper, Lining and backer sustainable leather Design**

This figure shows the marking guidelines on leather sheets before cutting the upper, lining, and backer pieces. Proper marking helps minimize material wastage and enhances accuracy during manual or CNC cutting. The method supports sustainable production by ensuring that leather offcuts can be reused or recycled effectively.

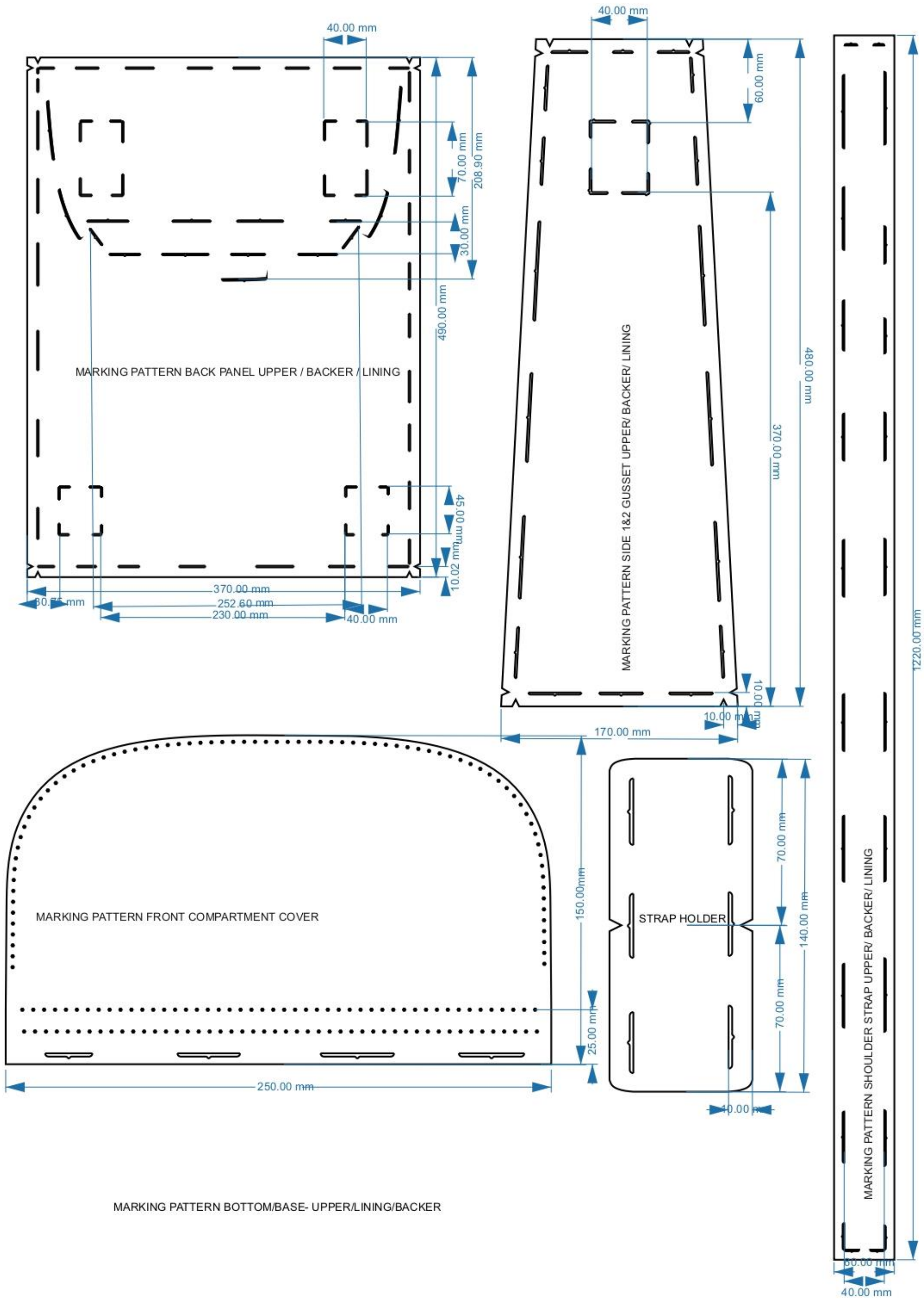


**Figure 8: Marking Pattern sketch Upper, Lining and backer sustainable leather Design**

Figure 8 highlights marking and layout for gusset-related elements, focusing on maximizing surface area utilization of sustainable leather sheets. The markings follow optimized placement for consistent seam allowances and structural integrity, ensuring both performance and eco-efficiency.

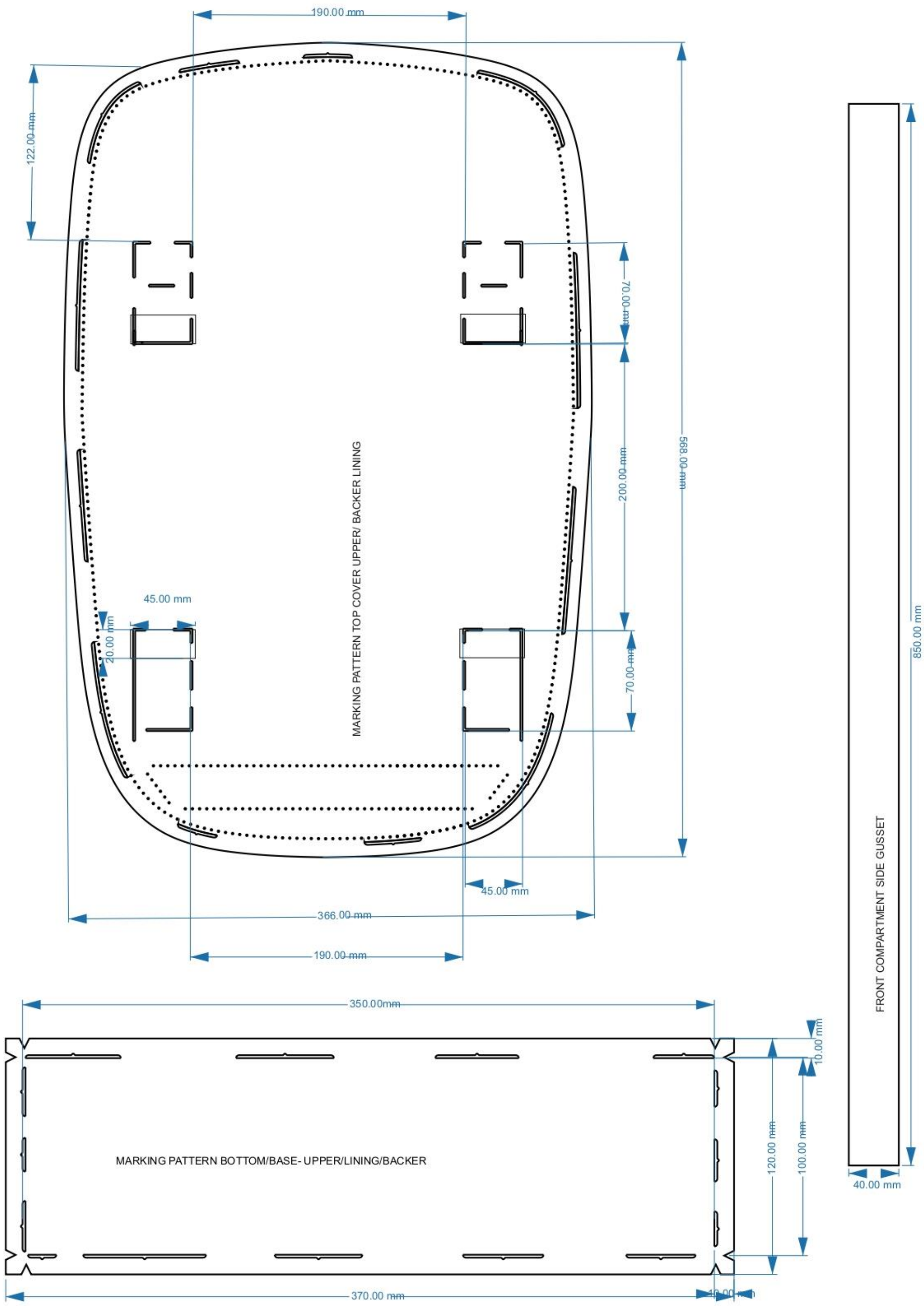


**Figure 9: Marking Patterns sketch Upper, Lining and backer sustainable leather Design**

Though not detailed in the document, Figure 9 likely presents either the assembled prototype or a final pattern layout combining all parts (upper, gusset, lining, backer). It demonstrates how sustainable materials and thoughtful design translate into a complete accessory, supporting the core principles of circularity, modularity, and visual appeal in eco-friendly leather goods

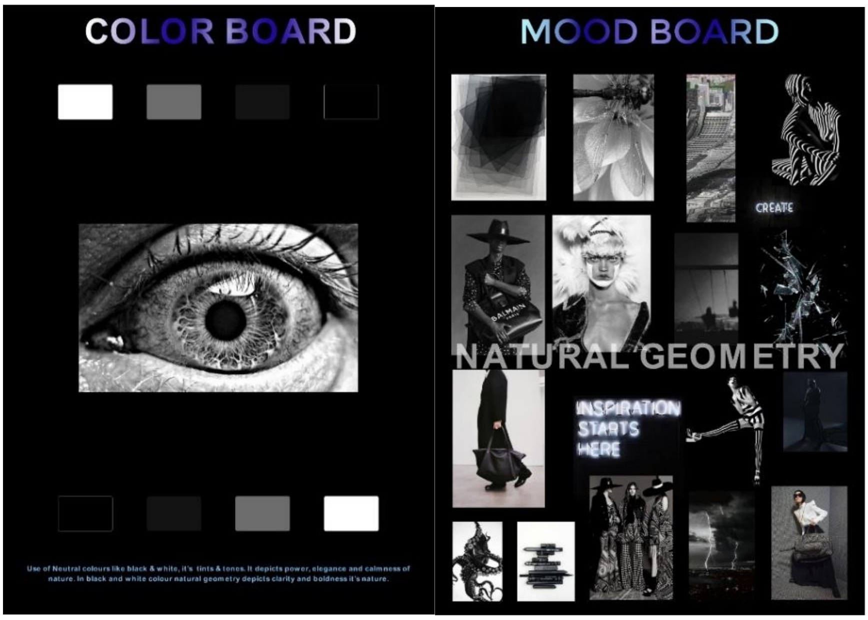


**Figure 10: Colour Board and Mood Board for Sustainable Leather Accessory Design**

This figure visually represents the inspiration, emotion, and design direction for the eco-friendly leather product line.

- Colour Board:
  - Features a curated palette of earthy, muted, or natural tones such as olive green, tan, rust, charcoal, and beige.
  - Colors are selected to reflect the organic origin of materials (vegetable-tanned, recycled, bio-leather).
  - Ensures consistency in product aesthetics, material matching, and brand identity.
- Mood Board:
  - Combines images, textures, patterns, lifestyle photos, and material swatches.
  - Illustrates the design philosophy natural, minimalist, artisanal, and eco-conscious.
  - May include references to sustainability themes like slow fashion, circular economy, ethical craftsmanship, and biophilic design.

Purpose:

- Sets the creative tone for design development.
- Aligns designers and stakeholders on the emotional and visual direction of the product.
- Serves as a tool for material and component selection consistent with sustainable goals.

**Figure 11: Final Sustainable Material and Component Board for Accessory Prototyping**

This figure likely shows the finalized selection of materials, textures, and components used in the prototype development phase.

- Includes:
  - Swatches of vegetable-tanned leather, recycled leather, and bio-leather.
  - Samples of lining, threads, zippers, and eco-friendly adhesives.
  - Labels, fasteners, trims, or hardware made from biodegradable or recycled materials.

Purpose:

- Acts as a pre-production reference for materials used.
- Validates the eco-materiality choices based on color, texture, and usability.
- Helps manufacturers ensure consistency in sustainable material application.

**5. Conclusion**

This study affirms that sustainable innovation in leather accessories is not only feasible but imperative. The comparative analysis of vegetable-tanned, recycled, and bio-leather materials reveals distinct advantages and limitations for each. Vegetable-tanned leather offers strong mechanical performance and improved biodegradability over chrome-tanned leather, making it ideal for high-end, artisanal applications. Recycled leather promotes circularity and reduces environmental footprint, although it shows moderate mechanical strength. Bio-leather, especially mycelium-based types, presents exceptional eco-friendliness with high flexibility and biodegradability, yet its relatively lower tensile strength limits use in load-bearing designs.

The design and manufacturing community must adopt a nuanced, material-specific approach that aligns functionality with sustainability. Successful market integration will depend on innovation in biofabrication, designer adaptability, and heightened consumer awareness. Moreover, scalable production systems and policy incentives are critical to overcoming economic and regulatory challenges.

A design framework combining material science, eco-design principles, and circular economy strategies provides a roadmap for future development. As consumer values shift toward ethical consumption, sustainable leather goods are poised to redefine luxury and function. This transition marks a meaningful stride toward a more environmentally conscious fashion and accessories industry.

**Reference:**

1. Jillian F, Qua S, In Management BS, et al. *(Im)Material: A Qualitative Study on Sustainable Materials for Design Through a Comparative Review of Leather and Its Modern Alternatives Signature redacted Signature of Author Integrated D 9 )d Management Program Signature redacted Signature redacted*. 2019.
2. T Loganathan, Elayaraja K, Vishva kumar M. Eco-Friendly Leather: Durable and Crack-Resistant Shoe Uppers By IJISRT. *International Journal of Innovative Science and Research Technology (IJISRT)* 2024; 861–864.
3. Anogna Angelina Y. *Comparative Evaluation of Leather and Polyester Non-Woven Materials for Sports Footwear Applications*.
4. T L. Optimization Study Analysis in Sustainable Materials for Sports Footwear. *African Journal of Biomedical Research* 2024; 1889–1899.
5. China CR, Maguta MM, Nyandoro SS, et al. Alternative tanning technologies and their suitability in curbing environmental pollution from the leather industry: A comprehensive review. *Chemosphere*; 254. Epub ahead of print 1 September 2020. DOI: 10.1016/j.chemosphere. 2020.126804.
6. Nur-E-Alam M, Mia MAS, Ahmad F, et al. An overview of chromium removal techniques from tannery effluent. *Applied Water Science*; 10. Epub ahead of print 1 September 2020. DOI: 10.1007/s13201-020-01286-0.
7. LoganathanT. PENTAHYDRATE COPPER SULPHATE TANNING SYSTEM. *International Journal of Research and Analytical Reviews*; 7, www.ijrar.org (2020).

8. Loganathan T, Faculty J, Loganathan MT. *Optimizing Revolution Development of Low Cost Sustainable Glide Shoe in Biodegradability Study in Compost Environment*, www.ijisrt.com (2023).
9. Kumari S, Raju GS, Singh S, et al. Evaluation of the Environmental Performance of Traditional Leather Materials in Fashion Industry. In: *E3S Web of Conferences*. EDP Sciences, 2023. Epub ahead of print 6 October 2023. DOI: 10.1051/e3sconf/202343001107.
10. Raman A, Loganathan T, Elayaraja K, et al. *Enhancing Footwear Comfort: Preliminary Study On Material, Design, And GAIT Analysis*, http://www.veterinaria.org (2024).
11. Ramesh D. *EVALUATION STUDY ANALYSIS ABOUT THREE DIFFERENT TYPES OF LEATHER VS POLYESTER NON-WOVEN*, www.irjmets.com.
12. Omoloso O, Mortimer K, Wise WR, et al. Sustainability research in the leather industry: A critical review of progress and opportunities for future research. *Journal of Cleaner Production*; 285. Epub ahead of print 20 February 2021. DOI: 10.1016/j.jclepro.2020.125441.
13. Kumar V. Optimization Study Analysis of Vegetable Tanning Finishing Techniques in Shoes: Introduction of Colour Wheel Methodology. *African Journal of Biomedical Research* 2024; 747–754.
14. Liu X, Zhang X, Wang X, et al. Engineered, environmentally friendly leather-like bio-based materials. *Trends in Biotechnology* 2025; 43: 1104–1115.
15. Kodaloğlu M, Akarslan KODALOĞLU F. Environmentally-Friendly Recycled Leather-Reinforced Composites: Thermal and Acoustic Properties. *Temmuz 2024 Journal of Technical Science* 2024; 14: 29–34.
16. Amobonye A, Lalung J, Awasthi MK, et al. Fungal mycelium as leather alternative: A sustainable biogenic material for the fashion industry. *Sustainable Materials and Technologies*; 38. Epub ahead of print 1 December 2023. DOI: 10.1016/j.susmat.2023.e00724.
17. Kanagaraj JK, Panda RC, Vinodh Kumar MVK. Trends and advancements in sustainable leather processing: Future directions and challenges-A review. *Journal of Environmental Chemical Engineering*; 8. Epub ahead of print 1 October 2020. DOI: 10.1016/j.jece.2020.104379.
18. Acquier A, Carbone V, Massé D. *Technology Innovation Management Review How to Create Value(s) in the Sharing Economy: Business Models, Scalability, and Sustainability*. 2019.
19. Lee M, Jay J. *Strategic Responses to Hybrid Social Ventures*.
20. Kumar D, Prashant P, Loganathan MT, et al. Journal of Population Therapeutics & Clinical Pharmacology ANTHROPOMETRIC ESTIMATIONS USING HAND DIMENSIONS AMONG THE NORTH INDIAN POPULATION. 2024; 31: 1021–1042.
21. Singh PK, Chirade S, Taluja R, et al. Eco-Conscious Creation: Navigating the Nexus of Sustainability and Production Design. In: *E3S Web of Conferences*. EDP Sciences, 2023. Epub ahead of print 30 November 2023. DOI: 10.1051/e3sconf/202345301034.
22. Vinyes E, Oliver-Solà J, Ugaya C, et al. Application of LCSA to used cooking oil waste management. *International Journal of Life Cycle Assessment* 2013; 18: 445–455.
23. Franco MA. Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry. *J Clean Prod* 2017; 168: 833–845.