Journal of Information Systems Engineering and Management
2025, 10(15s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

The Application of 3D Printing in the Shoe Manufacturing Industry in Indonesia

Ellysa Kusuma Laksanawati[1], Tjokorda Gde Tirta Nindhia[2], Made Sudarma[3], Wahyu Susihono[4],
[1]Doctoral of Faculty of Engineering, University of Udayana Bali
[2]Departement of Mechanical Engineering, University of Udayana Bali
[3]Departement of Electrical Engineering, University of Udayana Bali
[4]Departement of Industrial Engineering, University of Sultan Ageng Tirtayasa, Cilegon
*Coresponding Author: ellysakl@yahoo.com

ARTICLE INFO

Received: 30 Nov 2024

Revised: 20 Jan 2025

Accepted: 02 Feb 2025

ABSTRACT

This publication investigates 3D printing technology's transformational impact on the Indonesian shoe manufacturing business. As the sector confronts problems such as fast market shifts, rising customer demands for customisation, and the need for sustainable production processes, 3D printing appears as a potential solution to increase efficiency, minimise waste, and boost product innovation. This study examines numerous applications of 3D printing in shoe design, development, and production using a comprehensive analysis of current literature and case studies. It investigates how manufacturers might use this technology to develop customised footwear based on particular consumer preferences, hence increasing customer pleasure and loyalty. The study also looks at the environmental benefits of 3D printing, such as lower material waste and energy usage compared to traditional production methods. Furthermore, industry stakeholders share insights into the obstacles and opportunities involved with using 3D printing technology, such as initial investment prices, required skill sets, and 3D printing integration into existing production workflows. Overall, the findings indicate that incorporating 3D printing into the Indonesian shoe manufacturing business is not only viable, but also critical to sustaining competitiveness in a global market. This document serves as a resource for firms interested in exploring the possibilities of 3D printing to improve creativity, sustainability, and responsiveness in their manufacturing processes.

Keywords: 3D printing, shoe manufacturing, customisation, sustainability

INTRODUCTION

The shoe manufacturing sector is undergoing a dramatic upheaval, fuelled by technological breakthroughs and shifting consumer demands. In Indonesia, a country recognised for its lively footwear market, the use of 3D printing technology opens up new avenues for creativity, efficiency, and sustainability. Traditional manufacturing processes confront constraints such as high production costs, long lead times, and environmental concerns, but 3D printing emerges as an attractive alternative that addresses these issues while allowing firms to respond more quickly to market changes.

3D printing, also known as additive manufacturing, enables the development of complicated geometries and customised designs that would be impossible to produce using traditional manufacturing methods. This skill is especially important in the footwear industry, where there is a growing need for personalised items that cater to specific preferences and foot shapes. Manufacturers may considerably minimise material waste and optimise manufacturing processes by using 3D printing, resulting in a more sustainable approach in an industry that is frequently criticised for its environmental impact.

Several studies have emphasised the benefits of 3D printing, such as speedier prototyping, shorter time to market, and greater design freedom. However, implementation of this technology in Indonesia's shoe manufacturing sector is still in its early phases. Initial investment costs, the requirement for specialised labour, and the integration of 3D printing into existing manufacturing workflows are all challenges that industry players and policymakers must address.

This magazine intends to investigate the existing applications of 3D printing technology in the Indonesian shoe manufacturing business, as well as its benefits and obstacles, and to provide insight into its future possibilities. This

research aims to contribute to a better understanding of how 3D printing might transform the landscape of footwear production in Indonesia, preparing it for long-term growth in a competitive global market.

LITERATURE REVIEW

The shoe manufacturing business is an important part of Indonesia's economy, contributing significantly to both domestic and export markets. Indonesia, as one of South-east Asia's leading footwear makers, has long been renowned for its labour-intensive manufacturing methods and craftsmanship[1]. However, the business is under increasing pressure to develop due to a number of issues, including worldwide competitiveness, quickly changing customer preferences, and sustainability concerns.

In recent years, there has been a significant shift towards personalisation in consumer products, including footwear[2]. Modern consumers are increasingly seeking products that reflect their unique styles and preferences. In this setting, traditional manufacturing processes, which often involve large-scale production of standardised products, fail to meet demand for customisation while avoiding high prices and lead times.

3D printing technology, often known as additive manufacturing, provides a breakthrough solution to these difficulties. 3D printing allows producers to create highly customised and sophisticated designs, opening up new options for creativity[3]. This technology enables the development of shoes that not only fit better but can also be customised to specific sporting or lifestyle requirements. For example, brands can quickly create prototype designs, allowing for rapid testing and iteration before introducing new collections.

Furthermore, the sustainability component of 3D printing should not be disregarded[4]. Conventional shoe manufacturing is frequently associated with high material waste and energy usage. In contrast, 3D printing uses only the resources required for manufacture, potentially minimising waste and cutting the carbon footprint connected with footwear manufacturing[5]. This makes a compelling case for manufacturers looking to implement more ecologically friendly processes in response to rising consumer awareness and regulatory demands on sustainability.

Despite the potential benefits, the implementation of 3D printing in Indonesia's shoe manufacturing sector confronts some challenges[6]. These include high initial investment costs, the requirement for specialised personnel to run and maintain 3D printing devices, and the incorporation of this technology into existing industrial workflows. As a result, stakeholders who want to effectively exploit 3D printing in Indonesia's footwear industry must first comprehend the present situation and potential of the technology.

This journal will look at the many applications of 3D printing in the Indonesian shoe manufacturing business, highlighting both the benefits and the obstacles that come with its deployment. This study intends to add to the continuing discussion about the future of footwear production in an increasingly digital and consumer-driven economy by providing insights into real-world applications as well as the viewpoints of industry stakeholders[7].

METHODS

This study uses a qualitative research approach, supplemented by case studies, to investigate the use of 3D printing technology in the Indonesian shoe manufacturing business[8]. The goal is to get a thorough understanding of how 3D printing is being integrated into production processes, the benefits it offers, and the problems that industry participants confront[9].

1. Data Collection.

In-depth semi-structured interviews were performed with important stakeholders in the footwear manufacturing business, including:

1. Manufacturers: Managers and technical leaders from businesses that are currently employing or investigating 3D printing technologies in their operations[10].
2. Industry experts are professionals and academics who specialise in footwear manufacturing and 3D printing technologies[11].
3. Suppliers: Partners who provide 3D printing materials and technologies.

Two case studies were chosen from famous shoe manufacturers in Indonesia that have effectively integrated 3D printing into their manufacturing processes. These case studies show real-world applications of 3D printing in design, development, and production. The case study selection criteria comprised the following:

1. The extent of 3D printing implementation.
2. Product variety (sports shoes, casual footwear, etc.).
3. 3D printing enables innovation in design.

Data for the case studies were gathered through site visits, examination of production workflows, and a review of corporate papers demonstrating the 3D printing process[12].

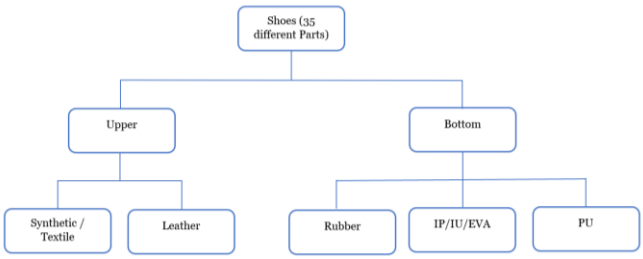

Figure 1. Bill of Materials (BOM) Shoe

Table 1. Example of Future craft 4D Shoes Production Life Cycle (Adidas)

Acquiring Raw Materials	**Manufacturing Process and Formulation**	**Distribution & Transportation**	**Use Re-Use and Maintenance**	**Recycling**	**Management Waste**
Raw Materials	Raw Materials	Raw Materials	Raw Materials	Raw Materials	Raw Materials
Primary fibres include cotton wool, alpaca, hemp, flax, silk, and water. Secondary fibres include nylon, spandex, liquid resins, and thermoplastic fused yarn.	Digital Light Synthesis Fused Yarn	Fossil Fuels	Recycled Paper Waste Materials	Some as Use Re-use Maintenance section. None	None
Adidas spun and twisted various raw materials to produce composite fibres and fused yarns. The Future Craft 4D is made in Germany as well. The shoe's technology and fibre quality were highly limited. Adidas claims that more than 90% of the materials it uses can be recycled.	Combination of thermoplastic yarn and polyester or nylon. The entire shoe upper is knitted at once using fused yarn, leaving no leftover components. The top is then attached to the sole, which is made using a 3D printing technique called Digital Light Synthesis by Silicon Valley startup Carbon. Digital Light Synthesis uses light and oxygen to generate 3D things from programmable liquid polymers.	The use of fossil fuels is unavoidable throughout the distribution phase. However, because the Future Craft 4D is limited to approximately 300 pairs domestically for the initial release, the distance traversed is reduced. Recycled paper and plastic. The shoe boxes for Future Craft 4D are created from recycled paper and plastic.	Adidas created boxes for its Take Back Programme, which encourages consumers to recycle used merchandise.	This stage of the life cycle does not require any more-raw materials.	This stage of the life cycle requires no additional raw materials.
Embodied Energy	Embodied Energy	Embodied Energy	Embodied Energy	Embodied Energy	Embodied Energy
Irrigation is the primary energy user, with fossil	Adidas Prime knit is processed using a Stoll	Raw materials are transferred to Germany for	Adidas Futurecraft 4D shoes are	Customers can donate their sneakers at a	None

Acquiring Raw Materials	Manufacturing Process and Formulation	Distribution & Transportation	Use Re-Use and Maintenance	Recycling	Management Waste
fuels such as diesel utilised to power tractors and machinery (chemical energy). Wool is spun into threads (using mechanical energy). Hemp is collected on farms and put through a process of chemical retting (mechanical and chemical energy). Retting is the process by which flax is combed through metal-tined combs known as hackles. Silk is harvested by hand and then processed through a succession of equipment onto rollers (mechanical and chemical energy). Nylon is manufactured by melting and drawing nylon chips into a spinneret. Polymerisation and melt spinning are used to convert polyester into a fabric material.	CMS 530 HP Machine, a high-productivity computerised flat knitting machine. The material is subsequently routed through a moving carriage, yarn feeders, and needle beds. The main appeal of Future Craft 4D shoes is that they are 3D printed using Carbon technology. Carbon 3D printers build the shoe's bottom half using Digital Light Synthesis and CLIP technology. In other words, the shoe sole was invented by a printer that used light, oxygen, and a light-sensitive polymer liquid resin. Adidas is constantly upgrading its manufacturing methods, therefore the entire process of producing Adidas Future Craft 4D shoes is carried out entirely by highly modern machines.	manufacture. The shoes are then exported from Germany to three locations in the United States. Shipping materials and products are transported by planes and ships. Because components and goods are carried internationally, the use of fossil fuels, such as petroleum gas, is extremely expensive.	designed to be worn like shoes, so the primary source of energy is human (mechanical energy). Because the shoes are handmade, they require little upkeep and require little energy to produce.	"Adidas Make Every Thread Count" booth in any Adidas Distribution Centre. The donated shoes are then processed according to various quality standards or recycled into a secondary raw material that is used to make new products. The donated shoes are either provided to individuals or organisations that help microenterprises in impoverished nations, or they are entirely recycled. The primary source of energy throughout this process is human work, but it is also used by machines to recycle non-reusable shoes (mechanical and chemical energy).	
Wastes & Emissions	Wastes & Emissions	Wastes & Emissions	Wastes & Emissions	Wastes & Emissions	Wastes & Emissions
Some materials, like as cotton, require cool-powered CO_2 emissions into the atmosphere. Similarly, normal nylon and	The Digital Light Synthesis apparatus is driven by electricity, which results in the combustion of fossil fuels. It	Because Adidas receives global assistance, primarily from Germany, modes of transportation are vital. At extremely high	Because of the sturdy 3D printed platform and tightly knit top outer, there should be little waste at this	The process of donating, collecting, and shipping discarded products to Germany needs transportation,	The shoe's upper exterior can be recycled and reused, however the 3D printed platform is not biodegradable.

Acquiring Raw Materials	Manufacturing Process and Formulation	Distribution & Transportation	Use Re-Use and Maintenance	Recycling	Management Waste
polyester can help lower these emissions. Liquid resins are derived from natural gas and oil, resulting in fossil fuel combustion and CO2 emissions.	does, however, reduce the need for injection moulding, which is time-consuming and wasteful of materials.	altitudes, aeroplanes produce huge amounts of CO2, nitrogen oxides, and water vapour into the atmosphere. These emissions raise the earth's surface temperature, contributing to global warming.	point in the shoe's lifecycle. However, if necessary, consumers can return the product to be properly recycled using the Take Back Programme boxes.	which emits pollutants like as CO2 into the atmosphere.	The 3D platform may be ground down, melted down, and converted into plastic filament to be reused. This method is frequently unknown, expensive, and inconvenient; hence the majority end up in landfills. They are subsequently incinerated, which emits CO2 into the atmosphere.

2. Data Analysis.
Thematic analysis was used to examine interview transcripts and conclusions from case studies. The following actions were taken:
1. Coding entails identifying and categorising major parts of data linked to 3D printing uses, benefits, and obstacles[13].
2. Theme Development: Grouping codes into broad themes to convey insights gained from interviews and case studies[14].
A comparative analysis was performed on the insights collected from interviews and the findings from case studies to discover commonalities and differences in experiences and perceptions of the use of 3D printing in the industry[15].

3. Validation.
To increase the trustworthiness of the findings, member checking was used, in which participants were asked to examine and provide input on the data interpretations and conclusions[16]. This technique guarantees that the findings appropriately represent the opinions of the stakeholders concerned.

4. Ethical considerations.
The study followed ethical research methods, safeguarding the confidentiality of interview participants and getting informed consent prior to conducting interviews[17]. Participants were informed that their replies would only be used for research reasons. This methodology seeks to provide a thorough understanding of the role of 3D printing in the Indonesian shoe manufacturing industry[18], emphasising real-world applications, innovation potential, and the strategic importance of adapting to emerging technologies in an increasingly competitive market.

RESULTS

1.Current Applications for 3D Printing
Interviews and case studies indicated several important applications of 3D printing in the Indonesian shoe manufacturing industry:
1) Prototyping: Most firms used 3D printing for quick prototyping. This enabled them to swiftly produce and test shoe designs, decreasing the time from concept to market. For example, one firm reported a 50% reduction in prototype development time after employing 3D printing.[10]

2) Customisation: Several companies have begun to provide customised footwear solutions, allowing clients to tailor fit, design, and materials. One major sports shoe manufacturer established a system that allowed consumers to design their shoes online, with the final products made via 3D printing[11].
3) Small Batch Production: 3D printing allowed producers to create limited batches of specialised or unique footwear designs without the need for costly moulds, resulting in a more flexible manufacturing process[19].

2. Advantages of 3D printing.
Stakeholders recognised various benefits related to the deployment of 3D printing technology:
1) Cost reductions: Reducing material waste and eliminating expensive mold-making processes result in significant cost reductions[20]. One producer predicted an annual savings of about 20% in material costs.
2) Sustainability: Companies highlighted that 3D printing aligned well with their sustainability aims, lowering production's carbon impact and minimising waste[21]. The potential to employ recyclable materials in 3D printing techniques boosted environmental initiatives.
3) Competitive Advantage: Companies indicated that adopting 3D printing technology enabled them to respond faster to market developments and consumer needs, giving them a competitive advantage over traditional manufacturing rivals[3].
3. Challenges Faced
Despite the advantages, manufacturers experienced a number of problems while introducing 3D printing:
1) Initial Investment Costs: The high initial costs of 3D printing equipment and technology were identified as a barrier, particularly for small and medium-sized businesses (SMEs)[22].
2) Skill gaps: A scarcity of skilled workers capable of running advanced 3D printing technology and comprehending the complexity of digital design, materials, and manufacturing processes hampered widespread adoption.
Integration with Existing Processes: Some organisations found it difficult to integrate 3D printing into existing manufacturing workflows, necessitating changes to production planning and logistics.

DISCUSSION

The study's findings highlight 3D printing's transformational potential in the Indonesian shoe manufacturing business. The ability to quickly prototype, customise items, and create small batches can greatly improve flexibility and response to market demands and consumer preferences. As the desire for personalised footwear grows, the advantages of 3D printing may become more important for manufacturers looking to differentiate themselves in a competitive landscape.
Furthermore, the environmental benefits associated with reduced waste and energy usage make 3D printing an essential component of sustainable production processes. As consumers grow more aware of the environmental impact of their purchases, companies that use 3D printing for sustainability may experience increased brand loyalty and market share.
However, the issues identified underline the importance of a systematic approach to utilising 3D printing technology. Investment in workforce development to close skill gaps is critical, as is the pursuit of public-private partnerships to encourage information transfer and lower initial investment barriers for SMEs. Furthermore, organisations may benefit from pilot programmes to test the integration of 3D printing into their existing operations prior to full-scale deployment.
In conclusion, while 3D printing's incorporation into the Indonesian shoe manufacturing business brings both opportunities and problems, its potential to modify production processes, improve customisation, and support sustainability initiatives is enormous. Further study and collaboration among industry stakeholders will be required to fully realise these benefits and drive the sector's future growth.

CONCLUSION

This report illustrates 3D printing technology's great potential to alter Indonesia's shoe manufacturing business. The findings show that 3D printing not only enables rapid prototyping and customisation, but it also improves operational efficiency and sustainability. 3D printing introduces a new paradigm for fulfilling the changing demands of consumers and the market by allowing producers to generate personalised footwear rapidly and cost-effectively.
The benefits of using 3D printing, such as decreased material waste, cheaper production costs, and the capacity to respond quickly to market changes, make it an important instrument for competitiveness in the Indonesian footwear business. Furthermore, the environmental benefits connected with this technology are consistent with the global push for sustainability, making it an appealing alternative for businesses looking to reduce their environmental imprint.
However, the study also cites significant barriers to the widespread adoption of 3D printing, such as high initial investment prices, skill shortages, and integration concerns with current manufacturing processes. To overcome these

obstacles, industry stakeholders must engage in worker training, form strategic alliances, and investigate alternative financing options, particularly for small and medium-sized businesses (SMEs).

To summarise, the successful integration of 3D printing into the Indonesian shoe manufacturing business has the potential to generate innovation, improve consumer satisfaction, and encourage sustainable practices. Future study should focus on longitudinal studies to assess the long-term influence of 3D printing on industry performance, as well as further investigation into technology improvements that could address the existing issues faced by businesses. As the industry evolves, adopting 3D printing may be a critical aspect in gaining a competitive advantage in the worldwide market.

REFRENCES

[1] S. Mehta, "Innovation systems, value chains and industrial clusters in developing economies: Case of Jalandhar's sports goods industry," *African Journal of Science, Technology, Innovation and Development,* vol. 16, no. 1, pp. 99-112, 2024.

[2] J. Pallant, S. Sands, and I. Karpen, "Product customization: A profile of consumer demand," *Journal of Retailing and Consumer Services,* vol. 54, p. 102030, 2020.

[3] A. Beltagui, N. Kunz, and S. Gold, "The role of 3D printing and open design on adoption of socially sustainable supply chain innovation," *International Journal of Production Economics,* vol. 221, p. 107462, 2020.

[4] E. M. Maines, M. K. Porwal, C. J. Ellison, and T. M. Reineke, "Sustainable advances in SLA/DLP 3D printing materials and processes," *Green Chemistry,* vol. 23, no. 18, pp. 6863-6897, 2021.

[5] T. Spahiu, H. Almeida, A. Manavis, P. Kyratsis, and A. Jimeno-Morenilla, "Industry 4.0 for sustainable production in footwear industry," in *International Conference on Water Energy Food and Sustainability*, 2021, pp. 699-707: Springer.

[6] S. V. Jaiswal, D. V. Hunt, and R. J. Davies, "Construction 4.0: A Systematic Review of Its Application in Developing Countries," *Applied Sciences,* vol. 14, no. 14, p. 6197, 2024.

[7] B. Murugesan, K. Jayanthi, and G. Karthikeyan, "Integrating Digital Twins and 3D Technologies in Fashion: Advancing Sustainability and Consumer Engagement," in *Illustrating Digital Innovations Towards Intelligent Fashion: Leveraging Information System Engineering and Digital Twins for Efficient Design of Next-Generation Fashion*: Springer, 2024, pp. 1-88.

[8] S. Ahmad, S. Miskon, R. Alabdan, and I. Tlili, "Towards sustainable textile and apparel industry: Exploring the role of business intelligence systems in the era of industry 4.0," *Sustainability,* vol. 12, no. 7, p. 2632, 2020.

[9] A. Malik, M. I. U. Haq, A. Raina, and K. Gupta, "3D printing towards implementing Industry 4.0: sustainability aspects, barriers and challenges," *Industrial Robot: the international journal of robotics research and application,* vol. 49, no. 3, pp. 491-511, 2022.

[10] P. Holzmann, R. J. Breitenecker, and E. J. Schwarz, "Business model patterns for 3D printer manufacturers," *Journal of Manufacturing Technology Management,* vol. 31, no. 6, pp. 1281-1300, 2020.

[11] T. Z. Cui, R. K. Raji, J. L. Han, and Y. Chen, "Application of 3D Printing Technology in Footwear Design and Manufacture–A Review of Developing Trends," *Textile & Leather Review,* vol. 7, pp. 1304-1321, 2024.

[12] N. O. Olsson, E. Arica, R. Woods, and J. A. Madrid, "Industry 4.0 in a project context: Introducing 3D printing in construction projects," *Project Leadership and Society,* vol. 2, p. 100033, 2021.

[13] G. D. Goh, S. L. Sing, and W. Y. Yeong, "A review on machine learning in 3D printing: applications, potential, and challenges," *Artificial Intelligence Review,* vol. 54, no. 1, pp. 63-94, 2021.

[14] N. M. Deterding and M. C. Waters, "Flexible coding of in-depth interviews: A twenty-first-century approach," *Sociological methods & research,* vol. 50, no. 2, pp. 708-739, 2021.

[15] D. V. Ukobitz, "Organizational adoption of 3D printing technology: a semisystematic literature review," *Journal of Manufacturing Technology Management,* vol. 32, no. 9, pp. 48-74, 2021.

[16] J. Rose and C. W. Johnson, "Contextualizing reliability and validity in qualitative research: Toward more rigorous and trustworthy qualitative social science in leisure research," *Journal of leisure research,* vol. 51, no. 4, pp. 432-451, 2020.

[17] A. Xu, M. T. Baysari, S. L. Stocker, L. J. Leow, R. O. Day, and J. E. Carland, "Researchers' views on, and experiences with, the requirement to obtain informed consent in research involving human participants: a qualitative study," *BMC medical ethics,* vol. 21, pp. 1-11, 2020.

[18] D. D. Rochman and A. Anwar, "Make or buy: case study of 3D printing spare parts adoption," *International Journal of Psychosocial Rehabilitation,* vol. 24, no. 2, pp. 2940-945, 2020.

[19] U. Spina and R. Compaó, "Innovation ecosystems in the creative sector: im case of additive manufacturing and advanced materials for design," *Joint Research Centre,* p. 12092, 2021.

[20] G. Pelin, M. Sonmez, and C.-E. Pelin, "The Use of Additive Manufacturing Techniques in the Development of Polymeric Molds: A Review," *Polymers,* vol. 16, no. 8, p. 1055, 2024.

[21] H. Hegab, N. Khanna, N. Monib, and A. Salem, "Design for sustainable additive manufacturing: A review," *Sustainable Materials and Technologies,* vol. 35, p. e00576, 2023.

[22] R. e. Masa'deh, R. Al-Dmour, R. Masadeh, H. Al-Dmour, and A. H. Al-Dmour, "The Usage of 3D Printing Technology by Small-Medium Sized Enterprise in Jordan," in *The Effect of Information Technology on Business and Marketing Intelligence Systems*: Springer, 2023, pp. 593-616.