

# Powering of Digital Techniques and Their Role in Revolutionizing the Ethiopian Leather Industry A Systematic Review of Literature

**Teklay Asgedom Teferi\***

Manufacturing Industry Development Institute (MIDI); Leather and leather Products Industry Research and Development Center (LLPIRDC), Addis Ababa, P.O. Box 5, Code 1058, Ethiopia

**\*Corresponding Author:** Teklay Asgedom Teferi; Manufacturing Industry Development Institute (MIDI); Leather and leather Products Industry Research and Development Center (LLPIRDC), Addis Ababa, P.O. Box 5, Code 1058, Ethiopia, E-mail: teferitwoasgedom@yahoo.com

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## Abstract

The Ethiopian leather industry, long characterized by traditional practices and untapped potential, stands at a critical juncture. This review synthesizes extant literature to explore the transformative power of digital techniques and their potential to revolutionize the sector. The analysis reveals that the integration of technologies such as Computer-Aided Design (CAD), 3D prototyping, and the Internet of Things (IOT) is transitioning the industry from a resource-intensive, guesswork-based model to one of precision, efficiency, and data-driven decision-making. Specifically, digital tools are shown to enhance every stage of the value chain: from enabling virtual sampling and minimizing material waste in design, to optimizing chemical usage and monitoring environmental parameters in production through automated process control.

Furthermore, literature highlights the emergence of e-commerce platforms and digital supply chain management systems as pivotal for connecting Ethiopian producers directly with global markets, enhancing visibility, and improving responsiveness. However, the review also identifies significant barriers to adoption, including high initial investment costs, a scarcity of technical skills, and inadequate digital infrastructure. The paper concludes that while the potential for a digital revolution in the Ethiopian leather industry is substantial, its realization is contingent upon strategic investments in human capital, supportive policy frameworks, and public-private partnerships. Embracing this digital shift is not merely an option but a necessity for the industry to achieve global competitiveness, sustainable growth, and greater value addition.

**Keywords:** Digital Transformation; Leather Industry; Ethiopia; Computer-Aided Design (CAD); Industry 4.0; Sustainable Manufacturing; Value Chain; Technological Adoption

## 1. Introduction

The global leather industry is undergoing a profound transformation, driven by the relentless advancement of digital technologies. From automated design and precision manufacturing to data-driven supply chain management and hyper-targeted marketing, digitalization is reshaping competitive landscapes worldwide. However, for developing nations with rich raw material bases like Ethiopia, this digital shift presents both a formidable challenge and an unprecedented opportunity. The Ethiopian leather sector, long recognized for its high-quality raw hides and skins, has historically been constrained by traditional practices, limited value addition, and a focus on intermediate commodity exports rather than finished products [9]. This reliance on conventional methods has impacted its global competitiveness, efficiency, and ability to capture higher margins in the international market.

The integration of digital techniques offers a viable pathway to overcome these historical bottlenecks. Technologies such as Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) can revolutionize product development and precision cutting, minimizing material waste and enhancing design capabilities. Furthermore, the adoption of Enterprise Resource Planning (ERP) systems can integrate disparate functions from inventory management to customer relations fostering unprecedented operational transparency and efficiency [21]. The potential extends to the marketing realm, where e-commerce platforms and digital storytelling can create a direct bridge between Ethiopian leather artisans and global consumers, thereby building brand equity and capturing a larger share of the final product value.

### Objective

- This paper aims to critically analyze the power of emerging digital techniques and their specific role in revolutionizing the Ethiopian leather industry.
- The specific objectives to achieve this can be by:
  - Identifying key digital technologies such as CAD/CAM, IoT in production, ERP systems, and digital marketing platforms relevant to the leather value chain.
  - Evaluating the potential impact of these technologies on critical areas including product quality, operational efficiency, supply chain logistics, and global market access for Ethiopian leather firms.
  - Examining the primary challenges such as infrastructural gaps, financial constraints, and skill shortages that may hinder widespread digital adoption.
  - Proposing a strategic framework for the successful integration of digital tools to enhance the sector's global competitiveness and facilitate its transition from a commodity exporter to a hub of high-value, branded finished leather goods.

## 2. Methodology

### Research Philosophy and Approach

This study adopts a constructivist research philosophy, recognizing that the impact and perception of digital techniques are shaped by context, stakeholders, and existing industrial frameworks. The approach is qualitative and exploratory; aiming to synthesize existing knowledge, identify patterns, gaps, and future pathways. It is a descriptive-analytical review that seeks to interpret and structure the literature rather than merely summarize it.

## Review Design

The methodology follows a systematic literature review (SLR) protocol tailored for a focused, sector-specific analysis. The steps are designed to ensure comprehensiveness, relevance, and analytical rigor.

## Literature Search Strategy

Sources: Academic databases (Scopus, Web of Science, Google Scholar), institutional repositories (Ethiopian universities, research institutes like Leather Industry Development Institute - LIDI), reports from international organizations (UNIDO, FAO, World Bank), government policy documents, and reputable industry publications.

## 3. Literature Review

### 3.1. Key Roles of Digital Techniques

**3.1.1. Enhanced Production Efficiency and Quality:** A primary challenge in the Ethiopian leather sector has been inefficiency in production and inconsistent quality, leading to high waste and low profitability. Digital techniques are directly addressing these issues. In tannery operations, which are resource and chemical-intensive, automation and AI-driven monitoring systems are crucial. For instance, automated dyeing and finishing machines ensure consistent application, reducing water and chemical usage by precisely controlling quantities a significant improvement over manual methods [11]. Furthermore, AI and computer vision systems can be deployed for defect detection and grading of raw hides. Traditional grading is subjective and prone to human error, but these technologies objectively identify flaws and sort hides based on precise quality metrics, ensuring that only suitable hides move to subsequent costly processing stages [24]. This application of technology confirms that "automation and AI-driven monitoring systems significantly reduce production time and waste in tanneries" [36].

This digital transformation extends from tanneries to manufacturing plants. Here, technologies such as Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) are transformative. As noted in studies on advanced manufacturing, technologies such as CAD/CAM transform precision in pattern making and customization, leading to less material waste and improved product quality [20]. In the context of Ethiopia, where optimizing material usage is critical for cost-effectiveness, CAD allows designers to create and nest patterns digitally, maximizing the number of pieces cut from a single hide. This process of digital nesting is a recognized method for drastically reducing off-cuts and material waste, which is a key concern for sustainable and lean production [20]. Subsequently, CAM systems translate these digital patterns into instructions for automated cutting machines, which execute cuts with laser-like precision. This integration eliminates the inaccuracies of manual cutting and ensures every component meets exact specifications, a critical factor for quality assurance [15]. The synergy between CAD and CAM not only enhances operational efficiency but also elevates the final product's fit, finish, and overall quality, thereby enabling Ethiopian manufacturers to meet the stringent standards required for competitiveness in international markets [34].

**Facilitating Customization and Sustainable Practices:** Beyond efficiency, digital techniques empower the industry with capabilities for mass customization and more sustainable operations. The precision of CAD allows for easy modifications to designs, enabling manufacturers to offer personalized products such as custom-fit footwear or bespoke leather goods without significant delays or cost overruns. This agility is key to competing in modern, demand-driven global value chains [13]. Moreover, the drive for efficiency is intrinsically linked to sustainability. The reduction in material waste through optimized cutting and the decrease in chemical and water consumption through automated processes directly lower the industry's environmental footprint. As noted by [28], the adoption of clean-tech digital solutions in tanneries is essential for Ethiopia to comply with international environmental regulations and appeal to the growing market of eco-conscious consumers. Thus, the power of digitalization not only revolutionizes productivity and quality but also steers the Ethiopian leather industry towards a more sustainable

and ethically responsible future, a transition aligned with the broader principles of sustainable manufacturing technology [5].

**Improved Sustainability:** A primary driver of this transformation is the need for Improved Sustainability. The conventional leather tanning and manufacturing processes are notoriously resource-intensive and polluting. Digital innovations are key to addressing this environmental impact by enabling cleaner production methods and optimizing resource use. For instance, research and development into advanced tanning methods, such as ultrasound-assisted and microbial/enzymatic tanning, are heavily reliant on digital modeling and process control to ensure efficacy and scalability. These methods significantly reduce the reliance on water and toxic chromium salts [1]. As noted by [9], the adoption of such green chemistries is crucial for the Ethiopian industry to comply with international environmental standards and access premium markets.

Furthermore, digitalization extends to the manufacturing floor, where AI and computer vision are revolutionizing material utilization. A critical challenge in leather production is the irregular shape and varying quality of natural hides, leading to significant waste during the cutting phase. AI-powered nesting software can now analyze the unique contours and defects of each hide to generate optimal cutting patterns [31]. This maximizes the yield of high-quality leather pieces, drastically reducing waste [27].

This application of AI directly supports the principles of a circular economy by enhancing resource efficiency and ensuring that the maximum value is extracted from raw materials [4]. Through advanced data analytics and machine learning, AI systems can optimize material sorting, predict material quality, and identify optimal pathways for reuse and remanufacturing, thereby minimizing the industry's environmental footprint from cradle to gate [17,30]. The power of these digital techniques lies in their interconnectedness. IOT sensors can monitor the tanning process in real-time, ensuring conditions are perfect for newer, sustainable methods [6]. Data from these processes can then feed into AI systems that manage the entire supply chain, from predicting raw hide quality [35], to optimizing production schedules [40]. This creates a synergistic effect, where sustainability and efficiency are achieved simultaneously [2].

**Digital Platforms for Enhanced Supply Chain Management:** A primary challenge in the Ethiopian leather supply chain is the fragmentation and lack of visibility from raw material (hide and skin) sourcing to finished product delivery. Digital platforms are addressing this by creating centralized systems for data collection and management. Organizations like UNIDO have been instrumental in this regard. For instance, UNIDO has developed and implemented databases to monitor the performance and compliance of leather enterprises, tracking key metrics from input quality to production output (UNIDO, 2018). These platforms allow for better coordination among tanneries, manufacturers, and exporters, leading to improved planning and resource allocation.

The power of these platforms lies in their ability to aggregate data, making the supply chain more visible and manageable. As highlighted in a study on industrial development, such digital tools help "reduce information asymmetry and improve the overall performance of the value chain" [26]. The digitization of records pertaining to hide quality, curing processes, and chemical usage is a cornerstone of modern leather manufacturing. These systems are pivotal in identifying bottlenecks and reducing delays, as data analytics can pinpoint inefficiencies in the production workflow [33]. Furthermore, such traceability is essential for ensuring that stringent quality standards are maintained from raw material to finished product [29]. By providing a comprehensive data trail, these digital systems enhance process control and consistency, which directly contributes to strengthening the industry's reliability and reputation [23].

### **3.1.2. Block chain for Radical Transparency and Traceability**

While digital platforms can improve management, block chain technology offers a true paradigm shift in supply chain transparency and traceability. The global market, particularly in Europe and North America, is increasingly demanding verifiable

proof of sustainable and ethical sourcing [16]. In response, block chain's immutable, decentralized ledger can provide an unalterable record of every transaction and movement of a product, such as hide or leather, creating a trusted and auditable chain of custody [37]. This technological approach directly addresses the traceability challenges and information asymmetry that have long plagued complex supply chains [32].

This technology can document a product's journey from the individual animal at a specific farmer's cooperative, through the collection center, tannery, and manufacturing facility, all the way to the retail shelf. This level of detail is crucial for verifying claims about animal welfare, environmental compliance, and labor practices. As [38] argued, block chain implementation in food and luxury good supply chains "ensures data integrity and builds trust among stakeholders" (p. 2). In the context of Ethiopia, this directly addresses a key market barrier. A consumer purchasing a leather bag in Milan could, via a QR code, verify that the hide was sourced from an ethically managed farm in the Oromia region, tanned using environmentally compliant processes, and manufactured in an Addis Ababa factory adhering to international labor standards.

This transparency is not just a marketing tool; it is a powerful mechanism for building long-term consumer trust and brand equity. As Gessese (2021) further suggests, traceability systems are essential for Ethiopian leather to access premium market segments where provenance and sustainability are key purchasing drivers. By providing an unforgeable certificate of origin and process, block chain technology can empower Ethiopian producers to command higher prices and build stronger, more resilient relationships with international buyers.

### 3.1.3. Market Expansion and E-commerce: Bridging the Global Divide

A primary challenge for Ethiopian leather and leather product manufacturers has been limited access to international markets and real-time market intelligence. Digital technologies are dismantling these barriers, facilitating a direct connection between Ethiopian artisans and manufacturers and the global marketplace.

E-commerce platforms, in particular, have democratized market access. They allow small and medium-sized enterprises (SMEs), which form the backbone of the Ethiopian leather sector, to bypass traditional, multi-layered export channels and reach international consumers directly. This shift is crucial for moving up the value chain from exporting semi-processed leather to selling high-value finished products like shoes, bags, and garments. As noted in a study on technology adoption, "digital marketing and e-commerce platforms can significantly reduce transaction costs and enhance the visibility of Ethiopian leather products in the international market" [25]. This direct-to-consumer or direct-to-business (B2B) model not only increases profit margins but also allows firms to build their own brands and gain valuable customer feedback.

Beyond transactional platforms, informational digital initiatives play a critical role. A key example is the Leather Industry Development Institute (LIDI) of Ethiopia's online portal and associated digital resources. These platforms serve as a centralized hub of information, providing international buyers with data on Ethiopian tanneries, manufacturers, product quality standards, and sector news. This digital presence is vital for building trust and credibility with global partners who may be geographically distant and unfamiliar with the local industry landscape. Research on global value chains emphasizes that "access to information and communication technologies (ICTs) is a key determinant for integrating into global networks and upgrading within them" [12]. By offering transparent and accessible information, these websites effectively connect Ethiopian businesses with global opportunities that were previously out of reach.

The synergistic effect of e-commerce and digital market intelligence enables Ethiopian companies to move from being price-takers to value-creators. They can now conduct online market research to identify trends, adapt their designs to meet specific consumer preferences in Europe, North America, or other African countries, and market their unique value propositions such as eco-friendly tanning or traditional Ethiopian craftsmanship to a worldwide audience. This digital-powered market expansion

sion is not merely an incremental change but a fundamental restructuring of how the Ethiopian leather industry engages with the global economy, fostering sustainable development and economic resilience.

## 3.2. Innovation and Design

### 3.2.1. Key Roles of Digital Techniques in the Ethiopian Leather Sector

#### 3.2.1.1. Innovation and Design

The adoption of advanced digital tools is revolutionizing the design and prototyping phases. Technologies such as 3D printing and bio-printing enable rapid prototyping, drastically reducing the time and cost associated with developing new product samples. This allows Ethiopian manufacturers to respond more agilely to international fashion trends. Furthermore, Augmented Reality (AR) and Virtual Reality (VR) are enhancing the customer experience by enabling virtual try-ons and immersive product showcases, catering to the global consumer's growing preference for unique and personalized items. As highlighted in a study on sustainable manufacturing, digital tools facilitate mass customization and reduce waste by allowing for precise design and testing before physical production begins [3]. This is particularly relevant for promoting sustainability within the Ethiopian leather value chain.

#### 3.2.1.2. Knowledge Sharing and Capacity Building

A significant challenge in many developing industries is the dissemination of technical knowledge and best practices. Digital platforms are pivotal in bridging this gap. The development of specialized knowledge portals and digital libraries provides a centralized repository for technical information, tannery operation manuals, and international quality standards. This democratizes access to crucial knowledge, supporting continuous skill development for the local workforce. Research on technology adoption in developing economies emphasizes that "knowledge-intensive platforms are fundamental for building endogenous capacity and fostering innovation" [22]. By empowering designers, technicians, and artisans with readily accessible information, Ethiopia can cultivate a more skilled and innovative industrial base.

#### 3.2.1.3. Supply Chain and Production Optimization

Beyond design, digital techniques are critical for optimizing the entire supply chain. The Internet of Things (IOT) can be deployed to monitor conditions in raw material storage and during the chemical tanning process, ensuring optimal quality control. Enterprise Resource Planning (ERP) systems integrate operations from procurement to sales, enhancing transparency and efficiency. A case study on the Indian leather industry found that ERP implementation led to significant improvements in inventory management and on-time delivery rates [20]. For Ethiopia, such integration can minimize losses, reduce lead times, and enhance the traceability and sustainability credentials of its leather products, which is increasingly demanded by global consumers.

#### 3.2.1.4. Persisting Challenges and the Path Forward

Despite the clear potential, the digital revolution of the Ethiopian leather industry faces significant hurdles. Key challenges include the high initial cost of investment in advanced technologies, a significant gap in digital skills among the workforce, and the need for a more robust and reliable ICT infrastructure nationwide [8].

The successful navigation of these challenges requires a concerted effort. The government's Digital Transformation Strategy (2021-2030) provides a crucial policy framework. Its effective implementation must be coupled with public-private partnerships to facilitate technology transfer and investment. Furthermore, integrating digital literacy and technical training into voca-

tional and university curricula is essential to build a future-ready workforce.

## 4. Conclusion and Recommendation

### 4.1. Conclusion

The literature review confirms that digital techniques hold transformative potential for the Ethiopian leather industry, a sector of critical economic and export importance. The adoption of technologies such as Computer-Aided Design (CAD), 3D prototyping, the Internet of Things (IoT) for process monitoring, Artificial Intelligence (AI) for quality inspection and demand forecasting, and block chain for traceability can fundamentally address the industry's longstanding challenges. These include improving design capabilities and product diversification, enhancing quality consistency, reducing material waste and production lead times, ensuring supply chain transparency, and meeting the stringent sustainability and traceability demands of the global market.

However, the review also reveals significant barriers to this digital revolution. These are primarily infrastructural (unreliable power, limited high-speed internet), financial (high upfront investment costs), and human capital-related (a scarcity of digital skills and technical expertise). Furthermore, the predominantly small and medium-sized enterprise (SME) structure of the industry and a sometimes-resistant traditional mindset further complicate widespread adoption. While pilot projects and initiatives show promise, a cohesive national strategy and stronger public-private partnerships are needed to move from isolated success stories to industry-wide transformation.

In essence, digitalization is not merely an operational upgrade but a strategic imperative for the Ethiopian leather industry to ascend the global value chain, shift from commodity exports to branded, high-value products, and build a resilient, competitive, and sustainable future.

### 4.2. Recommendations

Based on the findings of the literature review, the following multi-stakeholder recommendations are proposed:

#### **For the Government and Policymakers:**

- **Develop a National Digital Roadmap:** Formulate and implement a focused "Leather Industry 4.0" strategy with clear incentives (e.g., tax breaks, subsidies) for technology adoption.
- **Invest in Enabling Infrastructure:** Prioritize improvements in reliable electricity supply and affordable, high-speed broadband internet, particularly in industrial clusters.
- **Establish Digital Innovation Hubs:** Create sector-specific hubs that offer SMEs access to shared advanced technologies (like 3D printers and CAD software), training, and technical support.
- **Revise Education and Training Curricula:** Collaborate with universities and TVET institutions to embed digital skills (digital design, data analytics, and automation basics) into leather technology and engineering programs.

#### **For Leather Industry Associations and Clusters**

- **Promote Collaboration and Knowledge Sharing:** Organize workshops, demos, and success-story forums to reduce resistance and build a culture of innovation.

- **Facilitate Bulk Procurement:** Negotiate collective purchasing agreements for software and hardware to reduce costs for member SMEs.
- **Advocate for Supportive Policies:** Act as a unified voice to communicate industry-specific challenges and needs to policymakers.

#### **For Leather Enterprises (Large and SMEs)**

- **Adopt a Phased Digitalization Approach:** Start with low-risk, high-return technologies (e.g., digital inventory management, basic CAD) before scaling to more complex systems like AI and IoT.
- **Invest in Workforce Up skilling:** Partner with training providers to equip current employees with essential digital literacy and technical skills.
- **Explore Partnerships:** Collaborate with technology providers, universities, or larger firms on pilot projects to share risks and gain experience.

#### **For Academia and Research Institutions**

- **Focus on Applied and Localized Research:** Conduct research on adapting digital tools to local contexts, such as using AI for grading indigenous raw hides or optimizing processes for local conditions.
- **Strengthen Industry-Academia Linkages:** Offer consultancy services, internship programs, and joint R&D projects to solve real industry problems.

#### **For Technology Providers and Development Partners**

- **Develop Affordable, Context-Appropriate Solutions:** Create scalable, modular, and low-maintenance digital tools suited for the Ethiopian market.
- **Offer Flexible Financing Models:** Provide subscription-based (SaaS) or pay-per-use models to lower the entry barrier for capital-constrained firms.
- **Support Capacity Building:** Integrate comprehensive training and long-term technical support into technology deployment packages.

## **5. Author's Contribution**

Not applicable

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The author declares that there is no conflict of interest with respect to the authorship or publications of this manuscript.

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