

# Industrial Digitalization in Retail Furniture Manufacturing in Developing Countries

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## Abstract

Industrial digitalization has become an essential driver of competitiveness and productivity across manufacturing sectors. However, its adoption remains uneven in developing countries, particularly in industries characterized by customized production and operational complexity. This study focuses on industrial digitalization in the retail furniture manufacturing sector, where firms must respond to highly specific customer demands, short delivery times, and frequent design changes. The study examines research published between 2020 and 2025 to identify key opportunities and challenges shaping digital transformation in this sector by using bibliometric analysis and VOSviewer. Data were collected from the Web of Science database and Google Scholar. The findings indicate that digital technologies such as CAD/CAM systems, CNC machinery, ERP platforms, and Industry 4.0 applications offer significant potential for improving efficiency and flexibility. Nevertheless, firms continue to face constraints related to infrastructure readiness, investment capacity, and digital skills. The study emphasizes that digital transformation in retail furniture manufacturing represents a sector-specific and structural process that requires coordinated technological, organizational, and policy-level support in developing economies.

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## 1. Introduction

Digital transformation has become a defining feature of contemporary manufacturing as firms increasingly seek to improve efficiency, flexibility, and competitiveness in rapidly changing markets. Advances in digital technologies under the Industry 4.0 framework—such as automation, data analytics, and interconnected production systems—have significantly reshaped traditional manufacturing processes (Frank et al., 2020; Ghobakhloo, 2020). These technologies enable firms to optimize production flows, reduce lead times, and respond to growing market uncertainty.

Despite the increasing diffusion of Industry 4.0 technologies, their adoption remains uneven across regions and sectors. Research consistently shows that firms operating in developing countries face structural and institutional barriers that limit digital transformation efforts, including limited access to financial resources, weak digital infrastructure, and shortages of skilled labor (Moeuf et al., 2020; Estensoro et al., 2022). Small and medium-sized enterprises (SMEs), which dominate the manufacturing sectors in developing economies, especially face these challenges.

The retail furniture manufacturing sector represents a unique context for examining digital transformation. Unlike mass-production industries, furniture manufacturing is characterized by high levels of customization, project-based production, and frequent design modifications. To manage this complexity, firms rely on digital design and manufacturing technologies, such as CAD/CAM systems, CNC machinery, and integrated production planning tools (Da Silveira et al., 2022; Červený et al., 2022). These technologies are key for coordinating design, production, and installation while maintaining cost, efficiency, and delivery reliability.

However, empirical evidence suggests that many furniture manufacturers remain at early stages of digital maturity, particularly in developing economies. Studies indicate that organizational readiness, management commitment, and workforce digital skills play a key role in determining the success of digital transformation initiatives (Mittal et al., 2020; Sony & Naik, 2020). In the absence of these capabilities, investments in advanced technologies often fail to generate expected performance improvements (Rauch et al., 2023).

Given these challenges, there is a growing need for sector-specific analyses that examine how digital transformation unfolds in customized manufacturing environments within developing countries. The study aims to explore digital transformation in the retail furniture manufacturing sector by synthesizing recent academic literature published after 2020. By focusing on Industry 4.0

technologies, customization-oriented production systems, and developing-country contexts, the study seeks to identify key drivers, benefits, and barriers shaping digitalization in this industry (Santos et al., 2023; Duzgun et al., 2025).

## 2. Literature review

Recent literature highlights that industrial digitalization and Industry 4.0 have become central themes in manufacturing research, particularly after 2020. Studies emphasize that digital technologies such as automation, data analytics, and interconnected production systems enable firms to improve efficiency, flexibility, and competitiveness (Frank et al., 2020; Ghobakhloo, 2020). However, the adoption of these technologies remains uneven across industries and regions. Research focusing on small and medium-sized enterprises (SMEs) indicates that firms in developing countries face greater challenges due to limited financial resources, weak digital infrastructure, and insufficient technological capabilities (Moeuf et al., 2020; Estensoro et al., 2022). These studies indicate that contextual and structural factors, rather than just technological availability, strongly influence industrial digitalization.

Within this broader context, recent research has begun to examine the implications of Industry 4.0 for furniture manufacturing and wood-based industries. The furniture sector is characterized by labor-intensive processes, fragmented production structures, and a high prevalence of SMEs, which affect digital transformation pathways (Červený et al., 2022; Rauch et al., 2023). Empirical studies indicate that while digital technologies offer significant potential for improving production planning, quality control, and process integration, many furniture manufacturers remain at early stages of digital readiness (Sony & Naik, 2020; Rauch et al., 2023). In developing economies, these challenges are further intensified by gaps in infrastructure and limited access to skilled labor, constraining the effective implementation of Industry 4.0 solutions (Santos et al., 2023).

A growing body of literature focuses on customization and flexibility as key drivers of digitalization in furniture manufacturing. Retail furniture production is inherently project-based and characterized by frequent design changes and customer-specific requirements. Studies on mass customization highlight that digital design tools such as CAD/CAM systems, CNC machinery, and integrated production planning platforms are essential for managing complexity and maintaining efficiency in customized production environments (Da Silveira et al., 2022; Moyano-Fuentes et al., 2022). Studies demonstrate that the integration of digital design and manufacturing technologies enhances

coordination between design, production, and installation stages, reducing lead times and operational disruptions (Kwon & Lee, 2023; Naldi et al., 2025). These findings underline the strategic role of digital technologies in enabling customization-oriented business models in the furniture sector.

Beyond production technologies, recent studies emphasize the importance of organizational, institutional, and policy-related factors in shaping digital transformation outcomes. Research indicates that successful adoption of Industry 4.0 technologies requires organizational readiness, management commitment, and workforce digital skills (Mittal et al., 2020; Sony & Naik, 2020). In developing countries, the absence of supportive policy frameworks and innovation ecosystems further limits firms' digital transformation efforts (Hammad, 2023; Duzgun et al., 2025). Additionally, sustainability-oriented studies suggest that digitalization can support resource efficiency and environmental performance in furniture manufacturing when combined with long-term strategic planning (Neto & Kessler, 2024). Overall, the literature portrays digital transformation in retail furniture manufacturing as a complex, multi-dimensional process shaped by technological, organizational, and contextual factors, particularly in developing economies (Rayhan et al., 2025).

### **3. Methodology**

The study adopts a qualitative design based on a bibliometric analysis combined with a systematic literature review. The objective of the methodology is to examine the structure, evolution, and dominant themes of recent academic research on digital transformation in the retail furniture manufacturing sector, with a focus on developing countries. Given the exploratory and literature-driven nature of the study, bibliometric analysis is considered an appropriate methodological approach, as it enables the systematic synthesis of existing research without the need for primary data collection.

The dataset for this study consists of 19 peer-reviewed journal articles published between 2020 and 2025. Relevant studies were identified through major academic databases by using a combination of keywords, such as industrial digitalization, Industry 4.0, retail furniture manufacturing, customization, and developing countries. To ensure the relevance and quality of the dataset, several inclusion and exclusion criteria were applied. Only journal articles and institutional reports published in English were included, while conference papers, theses, and non-peer-reviewed sources were excluded. The focus on post-2020 publications was deliberately chosen to capture the most recent developments and trends in digital transformation following the acceleration

of digitalization in manufacturing. As a result of the screening process, a total of 19 academic sources were selected for analysis.

To complement the bibliometric findings, a qualitative content analysis was conducted. Each selected study was systematically reviewed and summarized based on publication year, research aim, methodological approach, and key findings. This manual classification process enabled an understanding of how digital transformation has been conceptualized and implemented within the furniture manufacturing sector. The content analysis also facilitated the comparison of findings across studies, highlighting similarities and differences in research focus, methodological choices, and sector-specific challenges, particularly in developing-country contexts.

To enhance the reliability, the selection and analysis procedures were applied consistently across all sources. The use of predefined inclusion criteria and standardized classification categories supports the transparency and replicability of the research process. Validity was strengthened by combining bibliometric analysis with qualitative content analysis, capturing quantitative patterns and contextual insights. This methodological triangulation reduces the risk of subjective bias and provides an understanding of the literature.

Bibliometric analysis was employed to quantitatively examine publication patterns and thematic structures within the selected literature. The analysis focused on publication year distribution, keyword co-occurrence, and thematic clustering to identify dominant research trends and emerging topics in the field. Each article was systematically reviewed and summarized based on publication year, research purpose, methodological approach, and key study findings. To visualize relationships among keywords and research themes, the VOSviewer software was used. VOSviewer enables the graphical representation of bibliometric networks by mapping frequently co-occurring keywords and grouping them into thematic clusters.

#### **4. Findings and discussion**

Table 1 summarizes the demographic characteristics of 19 selected studies, highlighting their publication periods, geographical focus, specific industry they operate in, establishment sizes, and methodological approaches. The highest frequencies are in bold.

*Table 1. Demographics of selected studies*

Characteristics	Category	Frequency
<b>Publication Year</b>	2020	4
	2021–2022	5
	2023–2024	7
	2025	3
<b>Geographical Focus</b>	Developing countries	11
	Developed countries	4
	Mixed / global	4
<b>Industry Focus</b>	Furniture manufacturing	6
	Wood-based manufacturing	3
	General manufacturing	10
<b>Firm Size Focus</b>	SMEs	12
	Large firms	3
	Mixed firm size	4
<b>Research Method</b>	Empirical (survey/case)	8
	Conceptual / framework-based	5
	Systematic review	6

The analysis is based on the bibliometric summary and content analysis of studies in Table 1. Findings are interpreted by focusing on research themes, sector-specific patterns, and challenges for digital transformation in retail furniture manufacturing in developing countries. Table 2 presents the bibliometric summary of selected studies on digital transformation in retail furniture manufacturing.

*Table 2. Summary Publication year*

Author(s)	Aim of study	Method	Key findings
2020 Frank et al.	To analyze implementation patterns of Industry 4.0 technologies in manufacturing firms	Empirical analysis	Industry 4.0 technologies improve efficiency, but adoption varies by firm capability.
2020 Ghobakhloo	To examine digitalization and sustainability opportunities under Industry 4.0	Conceptual analysis	Digitalization supports sustainability when aligned with strategic planning.
2020 Moeuf et al.	To investigate Industry 4.0 adoption challenges in SMEs	Literature review	SMEs face financial, technological, and organizational barriers.
2020 Mittal et al.	To review Industry 4.0 maturity models	Literature review	Organizational readiness is critical for successful digital transformation.

2020	Sony & Naik	To identify key factors for Industry 4.0 readiness	Conceptual framework	Leadership and workforce skills strongly influence readiness.
2022	Červený et al.	To explore Industry 4.0 opportunities in the furniture sector	Case-based analysis	Furniture firms benefit from digital integration but face skill shortages.
2022	Da Silva et al.	To analyze mass customization enabled by digital technologies	Conceptual and empirical analysis	Digital tools enable customization without efficiency loss.
2022	Estensoro et al.	To examine SME transition to Industry 4.0	Resource-based analysis	Internal capabilities determine digital transformation success.
2022	Moyano-Fuentes et al.	To study smart manufacturing in retail fixture production	Empirical case study	Digitalization improves coordination in customized production.
2023	Rauch et al.	To assess Industry 4.0 readiness in wood-based SMEs	Survey-based study	Infrastructure and skills are key readiness factors.
2023	Javaid et al.	To review Industry 4.0 technologies and applications	Review study	Industry 4.0 technologies enhance flexibility and productivity.
2023	Maretto et al.	To synthesize digital technology adoption in manufacturing	Systematic literature review	Adoption trends increased significantly after 2020.
2023	Hammad	To propose a smart manufacturing framework for developing economies	Conceptual framework	Policy support and skills development are essential.
2023	Kwon & Lee	To examine digital design impact on furniture productivity	Empirical analysis	CAD/CAM improves productivity and process integration.
2023	Santos et al.	To identify digital transformation challenges in furniture SMEs	Empirical study	Financial constraints limit Industry 4.0 adoption.
2024	Neto & Kessler	To study digitalization and sustainability in furniture manufacturing	Empirical analysis	Digital technologies support sustainable production.
2025	Duzgun et al.	To measure Industry 4.0 adoption in developing countries	Scale development study	Infrastructure and human capital are decisive factors.
2025	Naldi et al.	To examine Industry 4.0-enabled mass customization	Conceptual framework	Industry 4.0 strengthens customization capabilities.
2025	Rayhan et al.	To analyze drivers and barriers of Industry 4.0 in developing countries	Empirical study	Institutional support influences adoption success.

Table 2 provides an overview of the selected studies in terms of publication year, research objectives, methodologies, and key findings. The distribution of publication years indicates a growing academic interest in digital transformation and Industry 4.0 after 2020, with a noticeable increase in studies published between 2022 and 2024. This trend reflects the accelerated digitalization of manufacturing sectors following global disruptions and increased competitive pressure. Similar patterns were observed in Industry 4.0 literature, which emphasizes the strategic importance of digital technologies in enhancing manufacturing resilience and flexibility.

The findings reveal that Industry 4.0 technologies, digital transformation, and smart manufacturing constitute the most dominant research themes across the reviewed studies. As summarized in Table 2, these themes are frequently associated with concepts such as customization, SMEs, and integrated production systems. This highlights the close relationship between digitalization and the need for flexibility in retail furniture manufacturing, where customer-specific designs and short delivery times are common. The literature consistently indicates that digital tools such as CAD/CAM systems, CNC machinery, and ERP platforms play a key role in coordinating design, production, and installation processes.

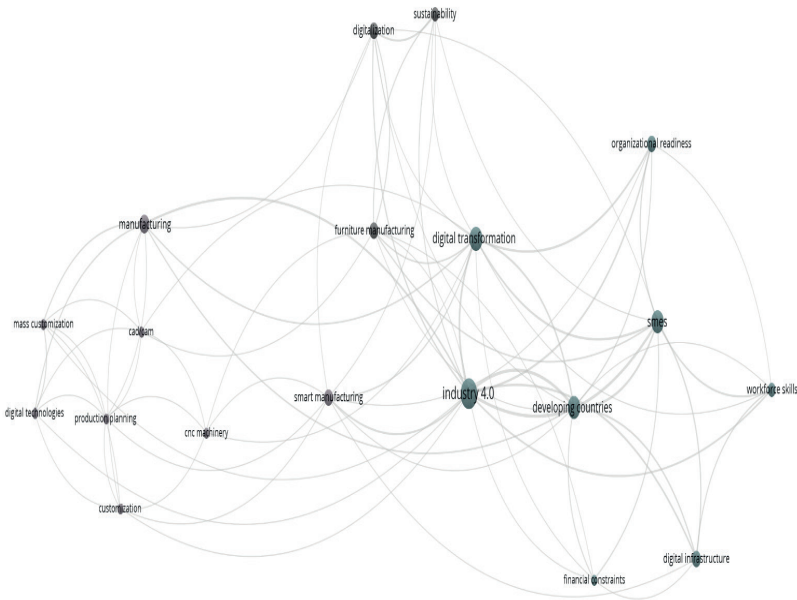
From a sector-specific perspective, results demonstrate that the complexity of customized production drives digital transformation in retail furniture manufacturing. Studies that focus on furniture and wood-based industries emphasize that digital design integration improves operational efficiency and reduces production errors. However, as discussed in several studies summarized in Table 1, the adoption level of advanced digital technologies remains uneven. While some firms demonstrate higher levels of digital maturity, many SMEs remain at early stages of Industry 4.0 implementation.

The discussion of the findings also highlights key challenges faced by firms operating in developing countries. Financial constraints, digital infrastructure, and skilled-labor shortages were identified as major barriers to digital transformation. The literature suggests that without adequate organizational readiness and external support mechanisms, firms struggle to fully realize the benefits of digital transformation.

Overall, the combined findings and discussion indicate that digital transformation in retail furniture manufacturing should be viewed as a multidimensional process shaped by technological, organizational, and contextual factors. The results support the argument that Industry 4.0 adoption in this sector requires not only technological investment but also strategic planning, workforce development, and supportive institutional frameworks.

These insights contribute to a better understanding of how digitalization unfolds in customized manufacturing environments within developing economies.

Figure 1 presents the keyword co-occurrence network generated through VOSviewer based on the 19 selected studies published between 2020 and 2025. Each node represents a keyword, with node size reflecting occurrence frequency and line thickness indicating co-occurrence strength between terms. The network reveals four distinct thematic clusters. The first cluster groups core digitalization concepts, including Industry 4.0, digital transformation, and smart manufacturing. The second cluster encompasses sector-specific terms such as furniture manufacturing, customization, CAD/CAM systems, and CNC machinery. The third cluster centers on developing countries and SMEs, connected to financial constraints and digital infrastructure. The fourth cluster links ERP platforms, organizational readiness, workforce skills, and sustainability. Overall, the network supports the multi-dimensional interpretation of digital transformation presented in this study.



*Figure 1. Keyword co-occurrence network of selected studies (VOSviewer, 2020-2025)*

## 5. Conclusion

This study examined digital transformation in the retail furniture manufacturing sector within developing countries by synthesizing recent academic literature published between 2020 and 2025. Using a bibliometric analysis supported by qualitative content analysis, the study aimed to identify dominant research themes, sector-specific patterns, and key challenges associated with Industry 4.0 adoption in customized manufacturing environments. The findings indicate that digital transformation has become a critical strategic priority for furniture manufacturers seeking to improve flexibility, efficiency, and competitiveness in increasingly dynamic markets.

The results demonstrate that Industry 4.0 technologies such as CAD/CAM systems, CNC machinery, ERP platforms, and integrated production planning tools play a central role in enabling customization-oriented production in the retail furniture sector. However, the analysis also reveals that the adoption of these technologies remains uneven, specifically among SMEs operating in developing economies. Organizational readiness, management commitment, and workforce digital skills emerge as decisive factors influencing the success of digital transformation initiatives.

From a broader perspective, the study highlights that digital transformation in retail furniture manufacturing should not be viewed as a technological shift. Instead, it represents a multidimensional process shaped by organizational capabilities, institutional frameworks, and contextual conditions. Financial constraints, limited infrastructure, and insufficient policy support continue to hinder the effective implementation of Industry 4.0 technologies in developing-country contexts. These findings underscore the need for coordinated efforts involving firms, policymakers, and educational institutions to support sustainable digital transformation in the sector.

### 5.1. Limitation and further research

Despite its contributions, this study has several limitations. First, the analysis is based exclusively on secondary data derived from published academic literature and does not include primary empirical evidence from firms or industry practitioners. Second, the scope is limited to literature published after 2020, which may exclude earlier foundational research on digital manufacturing. Finally, the bibliometric approach focuses on patterns and trends within the literature rather than direct measurement of operational performance outcomes.

Future research can address these limitations by incorporating empirical data through case studies, surveys, or semi-structured interviews with managers and

engineers in retail furniture manufacturing firms. Comparative studies between developing and developed economies might offer insights into contextual differences in digital transformation pathways. Additionally, future studies could explore the role of emerging technologies such as artificial intelligence, digital twins, and advanced analytics in further enhancing customization capabilities and sustainability in furniture manufacturing.

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