FEDERAL UNIVERSITY OF CEARÁ

CONTEXTUS
REVISTA CONTEMPORÂNEA DE ECONOMIA E GESTÃO
Contextus – Contemporary Journal of Economics and Management
ISSN 1678-2089
ISSNe 2178-9258
www.periodicos.ufc.br/contextus

Maturity of Industry 4.0 in small footwear companies: A comparative analysis of the understanding and practical application of the concepts

Maturidade da indústria 4.0 em pequenas empresas calçadistas: Uma análise comparativa da compreensão e da aplicação prática dos conceitos

Madurez de la Industria 4.0 en pequeñas empresas de calzado: Un análisis comparativo de la comprensión y la aplicación práctica de los conceptos

https://doi.org/10.36517/contextus.2026.96601

Jeferson Machado de Moura
https://orcid.org/0009-0007-9543-3237
Master's in Business Administration from Feevale University
jeferson.mooura@gmail.com

Dusan Schreiber
https://orcid.org/0000-0003-4258-4780
Professor at Feevale University
PhD in Business Administration from the Federal University of Rio Grande do Sul (UFRGS)
dusan@feevale.br

Luciane Pereira Viana
https://orcid.org/0000-0002-9577-728X
PhD in Cultural Diversity and Social Inclusion and Post-Doctorate in Administration from Feevale University
viana.luciane.lu@gmail.com

ABSTRACT

Background: Industry 4.0 is the convergence of digital and physical technologies, requiring systems integration and organizational transformation. Although researchers have widely discussed this convergence, the literature has lacked studies addressing traditional segments, such as the footwear industry and small businesses, where I4.0 adoption faces specific infrastructure and internal resource challenges.
Purpose: This study investigated the conceptual understanding and practical application of fundamental Industry 4.0 principles and components in small footwear companies across the Vale do Rio dos Sinos (Rio Grande do Sul State) region to identify variations in their digital maturity.
Method: This study employed a descriptive, qualitative multiple-case study design. Data collection triangulated information drawn from eight semi-structured interviews, systematic non-participant observation, and document analysis.
Results: The data showed different levels of digital maturity. In the category of Understanding Industry 4.0, companies ranged from initial to consolidated understanding. In Practical Application, early-stage companies focus on automation but lack sufficient resources; only one has demonstrated an advanced application with integrated systems and real-time decision-making.
Conclusions: The results show that the adoption of Industry 4.0 in small companies is at a digital maturity level characterized by a disconnect between understanding and application, conditioned by organizational capabilities. Digital transformation depends more on internal capacity to translate it into practices such as system integration, data management, and an organizational culture that supports change (intangible resources).
Keywords: Industry 4.0; digital transformation; organizational transformation; digital maturity; footwear sector.

RESUMO

Contextualização: A Indústria 4.0 representa a convergência de tecnologias digitais e físicas que exigem a integração de sistemas e a transformação organizacional. Embora amplamente discutida, a literatura carece de investigações que abordem segmentos tradicionais, como o calçadista e pequenas empresas, onde a adoção da I4.0 enfrenta desafios específicos relacionados à infraestrutura e aos recursos internos.
Objetivo: Investigar o nível de compreensão conceitual e a aplicação prática dos princípios fundamentais e dos componentes da Indústria 4.0 em pequenas empresas do setor calçadista do Vale do Rio dos Sinos/RS, identificando as variações na maturidade digital entre as organizações.
Método: Adotou-se uma abordagem qualitativa com caráter descritivo e estudo de caso múltiplo. A coleta de dados utilizou a triangulação de informações, incluindo oito entrevistas semiestruturadas, observação sistemática não participante e análise documental.
Resultados: Os dados mostraram diferentes níveis de maturidade digital. Na categoria Compreensão da I4.0, as empresas variaram de compreensão incipiente a consolidada. Na Aplicação Prática, empresas em estágio inicial focam na automação, mas sem recursos suficientes; apenas uma demonstrou aplicação avançada, com sistemas integrados e decisões em tempo real.
Conclusões: Os resultados mostram que a adoção da I4.0 em pequenas empresas está em maturidade digital, marcada pela dissociação entre compreensão e aplicação, condicionada pelas capacidades organizacionais. A transformação digital depende mais da capacidade interna de traduzi-la em práticas como integração de sistemas, gestão de dados e cultura organizacional que sustente a mudança (recursos intangíveis).

Information about the Article
Submitted on 18/03/2026
Final version on 28/04/2026
Accepted on 28/04/2026
Published online on 24/06/2026

Interinstitutional Scientific Committee
Editor-in-Chief: Diego de Queiroz Machado
Reviewed using the double-blind review system (SEER/OJS – version 3)

Palavras-chave: Indústria 4.0; transformação digital; transformação organizacional; maturidade digital; setor calçadista.

RESUMEN

Contextualización: La Industria 4.0 representa la convergencia de tecnologías digitales y físicas que exige la integración de sistemas y la transformación organizacional. Aunque se ha debatido ampliamente, la literatura carece de investigaciones que aborden sectores tradicionales, como la industria del calzado y las pequeñas empresas, donde la adopción de la I4.0 enfrenta desafíos específicos relacionados con la infraestructura y los recursos internos.

Objetivo: Investigar el nivel de comprensión conceptual y la aplicación práctica de los principios y componentes fundamentales de la Industria 4.0 en pequeñas empresas de calzado de la región del Vale do Rio dos Sinos (Rio Grande do Sul), identificando variaciones en la madurez digital entre las organizaciones.

Método: Se adoptó un enfoque cualitativo de carácter descriptivo y un estudio de casos múltiples. La recopilación de datos se realizó mediante triangulación de información, incluyendo ocho entrevistas semiestructuradas, observación sistemática no participante y análisis documental.

Resultados: Los datos mostraron diferentes niveles de madurez digital. En la categoría de Comprensión de la Industria 4.0, las empresas variaron desde una comprensión incipiente hasta consolidada. En Aplicación Práctica, las empresas en etapa inicial se centran en la automatización, pero sin recursos suficientes; solo una demostró una aplicación avanzada, con sistemas integrados y decisiones en tiempo real.

Conclusiones: Los resultados muestran que la adopción de la Industria 4.0 en pequeñas empresas está en un nivel de madurez digital, marcado por la disociación entre comprensión y aplicación, condicionada por las capacidades organizacionales. La transformación digital depende más de la capacidad interna para traducirla en prácticas como la integración de sistemas, la gestión de datos y una cultura organizacional que sostenga el cambio (recursos intangibles).

Palabras clave: Industria 4.0; transformación digital; transformación organizacional; madurez digital; sector del calzado.

How to cite this article:

Moura, J. M., Schreiber, D., & Viana, L. P. (2026). Maturity of Industry 4.0 in small footwear companies: A comparative analysis of the understanding and practical application of the concepts. *Contextus – Contemporary Journal of Economics and Management*, 24, e96601. https://doi.org/10.36517/contextus.2026.96601

1 INTRODUCTION

Industry 4.0 (I4.0) marks a transformative milestone in the global industrial landscape, characterized by the integration of technologies to improve operational efficiency and process sustainability (Hanauer, Schreiber, & Viana, 2024). Historically, global manufacturing has undergone sequential revolutions (Xu et al., 2018; Javaid et al., 2020): Industry 1.0, driven by the introduction of steam-powered mechanical systems; Industry 2.0, which brought electrification and mass production; and Industry 3.0, which integrated automation and microelectronics. I4.0, or the Fourth Industrial Revolution, has been described as the physical digitization of an organization's assets, creating a connected infrastructure that culminates in an electronic value chain in collaboration with partners (Bibby & Dehe, 2018).

I4.0 represents an industrial stage of digital system convergence (Frank, Dalenogare & Ayala, 2019) and has also been considered a managerial revolution that makes processes more robust and intelligent (Mahmood & Mubarik, 2020; Gadre & Deoskar, 2020). Arcidiacono et al. (2022) highlighted the benefits of smart factories, which constitute the core of this revolution. Advances in automation and data-driven decision-making have also become evident (Marum et al., 2022; Klingenberg et al., 2022; Monteiro et al., 2023). Elnadi and Abdallah (2024) described I4.0 as a philosophy that integrates the entire value chain in real time to optimize operations and increase competitiveness. Sustaining this philosophy requires observing fundamental principles such as virtualization, interoperability, decentralization, and real-time integration (Gilchrist, 2016). The enabling technologies of I4.0 are vast, grouped into categories, including the Internet of Things (IoT), cloud computing, and additive manufacturing (Cavalcante & Almeida, 2018). Successful adoption also depends on organizational factors, including training and human factors (Neumann et al., 2021; Cucculelli et al., 2021), as well as strategies that articulate operations, culture, and skills (Elnadi & Abdallah, 2024; Al-Khatib et al., 2024).

Despite extensive theoretical discussion regarding the benefits and challenges of I4.0, an empirical and theoretical gap persists in the scientific literature: a scarcity of empirical investigations exploring traditional manufacturing segments in specific geographic contexts. A search of the Web of Science database in October 2025, combining the terms "industry 4.0" and "footwear," yielded only 2 peer-reviewed articles. The two identified articles by Agolli et al. (2025) and Jimeno-Morenilla et al. (2021) highlighted this gap, noting that although the footwear sector is a relevant field, traditional sectors with lower levels of automation face specific challenges when adopting technological enablers. Jimeno-Morenilla et al. (2021) specifically highlighted the lack of empirical studies validating theoretical models of I4.0 adoption in traditional sectors. Agolli et al. (2025) identified a gap between I4.0 intention and realization, highlighting the need to investigate the factors (maturity, resources, skills) that hinder a complete transition in specific contexts.

Accordingly, this study empirically examines four small enterprises within a specific footwear hub and seeks to make a theoretical contribution by contextualizing the understanding of I4.0 maturity. It clarifies how structural limitations, internal skills, and managerial interpretations condition the translation of theoretical models into effective practices. Thus, the objective of this study is to identify the level of conceptual understanding and the practical application of I4.0 fundamental principles and components in small footwear enterprises in the Vale do Rio dos Sinos (Rio Grande do Sul State) region, and to examine variations in digital maturity among the organizations. The selection of small footwear manufacturing firms is justified by this segment's significance to the Brazilian economy; small enterprises constitute a vital portion of the sector, comprising over a thousand companies and tens of thousands of jobs (Abicalçados, 2024). Consequently, understanding how these firms have adopted I4.0 remains relevant, as implementing these technologies in smaller companies requires different approaches and resources compared to large players. This study aims to contribute academically by providing empirical data on a traditional sector underexplored in the I4.0 literature, and by validating and refining theoretical maturity models for small enterprises. Managerially, the results provide a comparative diagnosis that can assist managers in creating more effective strategic roadmaps for digital transition.

This study adopted a qualitative, descriptive method, employing a multiple-case study design across four small footwear companies. It utilized data triangulation through semi-structured interviews with eight managers, systematic non-participant observation, and document analysis. Data analysis was conducted using content analysis (Bardin, 2016). This article is structured into five sections. Following this introduction, the second section presents the theoretical framework, detailing the concepts, principles, and components of I4.0. The third section describes the methodological procedures. The fourth section presents and discusses the empirical results, comparing I4.0 maturity across the studied companies. Finally, the fifth section provides concluding remarks, managerial and academic implications, study limitations, and suggestions for future research.

2 THEORETICAL FRAMEWORK

Industry 4.0 (I4.0) represents the fourth industrial revolution, a stage characterized by the integration of technologies, cyber-physical systems, and automated processes. This transformational phase offers opportunities for the manufacturing sector, ranging from resource optimization to global economic growth, as indicated by Pagliosa et al. (2019) and Büchi et al. (2020). According to Bibby and Dehe (2018), I4.0 involves the digitization of physical assets and the creation of a connected infrastructure, whereas Silva et al. (2019), Pacchini et al. (2019), and Pagliosa et al. (2019) highlighted the capacity for real-time integration and communication among people, machines, and products.

Silva et al. (2019) defined I4.0 as a process of automation and technological integration aimed at digitizing productive activities, emphasizing efficiency and resource optimization. Pacchini et al. (2019) expanded this perspective by incorporating the notion of value creation and new services, shifting I4.0 from a strictly operational focus to a more strategic logic. Similarly, Pagliosa et al. (2019) emphasized interconnectivity and real-time communication between actors and systems, highlighting vertical and horizontal integration as structuring elements. These approaches, although distinct in emphasis, converge in positioning I4.0 as a systemic phenomenon in which technologies, processes, and business models interconnect.

Along these lines, Elnadi and Abdallah (2024) reinforced I4.0 as a manufacturing philosophy grounded in digitization and integration, while Mahmood and Mubarik (2020) highlighted its transformative character, qualifying it as a "managerial revolution." This interpretation suggests that adopting I4.0 is not limited to technological incorporation but implies profound reconfigurations of organizational structures and decision-making processes. Gadre and Deoskar (2020) and Arcidiacono et al. (2022) complemented this view by situating the smart factory as the core of this transformation, where, according to Monteiro et al. (2023), autonomous systems operate based on real-time data. Nevertheless, a relevant tension emerges: while the literature often describes an idealized model of high integration and autonomy, empirical evidence points to fragmented and unequal adoption trajectories (Arcidiacono et al., 2022).

This gap between conception and implementation can be partially explained by organizations' digital maturity, even though studies do not always explicitly articulate this construct. Furthermore, implementation can vary across markets and regions, underscoring the need for a comprehensive, adaptable industrial policy to integrate into the digital landscape (Hanauer, Schreiber, & Viana, 2025). Thus, although the fundamental principles of I4.0 (interoperability, virtualization, real-time capability, decentralization, modularity, systems integration (vertical and horizontal), and service orientation) have been widely disseminated (Gilchrist, 2016; Elnadi & Abdallah, 2024), their adoption remains complex and fraught with challenges, requiring companies to be aware of the difficulties inherent to this model (Elnadi & Abdallah, 2024).

Ghobakhloo and Iranmanesh (2018) and Culot et al. (2020) expanded this discussion by proposing a more comprehensive set of design principles, including service orientation, smart products and factories, interoperability, modularity, decentralization, virtualization, real-time capability, vertical and horizontal integration, product personalization, corporate social responsibility, IoT, and the internet of services. For these authors, these principles promote a more integrated and intelligent approach to meeting customer needs and improving process efficiency. Nevertheless, this multiplicity suggests that integrating I4.0 does not follow a linear or universal model but is mediated by strategic choices and contextual limitations.

At the technological level, enabling technologies materialize the principles of I4.0 by integrating the physical and digital worlds (Hanauer, Schreiber, & Viana, 2024). Frank, Dalenogare, and Ayala (2019) divided technologies into facilitating technologies (e.g., legacy software and networks) and core technologies (e.g., cyber-physical systems, IoT, artificial intelligence, and cloud computing); the latter are more recent and offer greater flexibility and automation. Cavalcante and Almeida (2018) proposed functional classifications: data analysis and processing (big data, machine learning), augmented reality, cloud computing, mobile devices, IoT, additive manufacturing, and cyber-physical systems. Frank, Dalenogare, and Ayala (2019) described a framework comprising front-end technologies (smart manufacturing, smart products, smart supply chain, and smart working) and base technologies (IoT, cloud services, big data, and analytics).

The success of I4.0 results from the effective integration of technologies that work to reduce the need for human intervention and increase efficiency (Singh et al., 2023). The interconnectivity enabled by these technologies allows systems to adapt dynamically and improve process efficiency (Allen, 2017; Marum et al., 2022), as well as promote corporate social responsibility (Ghobakhloo & Iranmanesh, 2018; Culot et al., 2020; Messeni Petruzzelli et al., 2022). Nevertheless, this same interconnectivity exposes companies to cybersecurity risks (Allen, 2017; Ghobakhloo & Iranmanesh, 2018; Culot et al., 2020). It also requires continuous professional training (Cucculelli et al., 2021) and high financial investments, in addition to confronting managerial resistance (Arantes et al., 2021; Hanauer, Schreiber, & Viana, 2025). Implementation likewise requires new organizational strategies and changes regarding operations, infrastructure, and human resources (Ghobakhloo & Iranmanesh, 2018; Ietto et al., 2022; Wang et al., 2020).

In this context, adopting I4.0 cannot be understood merely as a technological decision but rather as a process dependent on organizational capabilities. Arantes et al. (2021) structured these capabilities based on tangible, intangible, and human resources, highlighting that digital transformation requires an articulated combination of these elements. Tangible resources, including technological infrastructure, are necessary but insufficient without the support of intangible assets, such as organizational culture and knowledge, and adequate human competencies. Al-Khatib et al. (2024) reinforced this view by emphasizing the role of dynamic capabilities (e.g., learning, integration, and adaptation), especially within small and medium-sized enterprises.

Consequently, factors such as absorptive capacity (which promotes open innovation), desorptive capacity (which improves performance), external capabilities (which affect value creation and promote business model innovation), internal capabilities (which foster internal innovation), integration capability (which enhances performance), collaborative innovation capability (which improves digital collaboration capability), and social media capabilities (which boost performance and promote innovation) (Arantes et al., 2021) become critical to enabling the internalization and effective use of technological tools.

In summary, the literature suggests that I4.0 adoption emerges from the interactions among digital maturity, organizational capabilities, and technological availability. This conceptual articulation demonstrates that the transition to I4.0 is not merely a technical challenge but requires short-, medium-, and long-term goals; a dedicated team; cost analysis (Ghobakhloo & Iranmanesh, 2018); supply chain optimization; and intelligent business strategies (Hanauer, Schreiber, & Viana, 2025). These elements ensure that the potential benefits (encompassing sustainability and global economic growth) are effectively realized (Hanauer, Schreiber, & Viana, 2024).

3 METHODOLOGY

This study was derived from a broader investigation analyzing the impact of digital technologies on companies in the footwear sector. This article presents a specific, theoretically oriented analytical scope by focusing exclusively on the dynamics of understanding and incorporating I4.0-associated technologies. The relevance and autonomy of the investigated phenomenon justify this delimitation, as the literature still lacks empirical evidence that deeply links levels of conceptual understanding to their translation into organizational practices, particularly within small companies in traditional sectors. Consequently, the proposed scope provides an original contribution by advancing the explanation of the mechanisms mediating the transition between cognition and action in the context of digital transformation.

In accordance with this analytical scope, this study adopted a qualitative, descriptive methodological approach (Gil, 2019; Demo, 2022), operationalized through a multiple-case study following Yin's (2015) guidelines. This design proved particularly suitable for the proposed objective, as it enabled the exploration of the dynamics of understanding and applying I4.0 in real organizational contexts. Using multiple cases conferred greater analytical robustness to the study by enabling the application of replication logic, thereby facilitating the identification of convergent and divergent patterns across the investigated units.

The empirical corpus comprised four small companies in the footwear segment (Table 1), located in the Vale do Rio dos Sinos (Rio Grande do Sul State, southernmost Brazil). The region's status as a recognized hub of the national footwear industry justified this geographic delimitation, as it enhanced both the contextual relevance and the comparability of the analyzed cases (Governo do Estado do Rio Grande do Sul, 2025). Convenience and accessibility criteria guided the selection of the units of analysis. The small-size criterion, defined by a limited number of employees, focused the investigation on the organizational specificities of this segment, including structural limitations, resource constraints, and unique managerial challenges, all of which directly influence the appropriation of I4.0 technologies.

Table 1
Characteristics of the analyzed companies

Company	Founding	Employees	Average daily production	Primary focus
Alpha	15 years	50	1200	Cutting and preparation of synthetic materials for sports footwear
Beta	12 years	68	1800	Specialized in the production of insoles for women's shoes, with emphasis on modeling and assembly
Delta	25 years	65	2300	Dedicated to cutting and preparing leather for high-end footwear. Its operation requires high technical rigor and skilled labor
Gamma	10 years	76	2000	Specialized in the manufacture of rubber and TPU soles, serving the casual and safety segments

Source: Prepared by the authors.

We sought to ensure analytical variability by including companies with diverse production specializations within the prefabricated segment, encompassing activities such as material cutting and preparation, modeling, insole assembly, and sole manufacturing. We intentionally incorporated this heterogeneity into the research design to expand interpretative capacity, allowing us to observe different I4.0 maturity stages. Although the sample was not statistically representative, our selection logic met the assumptions of theoretical sampling by prioritizing informational richness and diverse analytical contexts. Regarding theoretical saturation, we did not strictly define the number of cases *a priori*. We evaluated saturation not only based on thematic repetition but also on the constructed analytical categories, ensuring they were sufficiently developed to support theoretical inferences. Consequently, limiting the corpus to four units of analysis proved methodologically consistent with the research objectives, balancing analytical depth and empirical diversity.

We structured data collection around three complementary techniques: semi-structured interviews, systematic non-participant observation, and document analysis (Yin, 2015; Marconi & Lakatos, 2017). This methodological triangulation aimed to enhance the study's internal validity by integrating multiple sources of evidence, thereby fostering a richer, more contextualized understanding of the investigated phenomenon. We conducted eight face-to-face interviews between March and April 2025. Participant selection (Table 2) followed purposive and strategic criteria, prioritizing individuals in leadership positions who possessed a comprehensive view of organizational processes, accumulated sector experience, and significant tenure at their respective companies.

Table 2

Profile of the Interviewees

Interviewee	Position	Company	Age (years)	Length of time with the company (years)	Length of time with the company (years)	Length of time with the company (years)
1	General manager	Alpha	48	10	High school diploma	20 (management and footwear industry)
2	Production manager	Alpha	38	7	Elementary school diploma	15 (industrial footwear production)
3	General manager	Beta	50	12	Some college (business administration)	22 (management and footwear industry)
4	Production manager	Beta	40	10	Some high school diploma	17 (industrial footwear production)
5	General manager	Gamma	45	9	Elementary school diploma	18 (management and footwear industry)
6	Production manager	Gamma	37	6	High school diploma	16 (industrial footwear production)
7	General manager	Delta	52	15	High school diploma (business administration)	25 (management and footwear industry)
8	Production manager	Delta	42	10	High school diploma	19 (industrial footwear production)

Source: Prepared by the authors.

We developed the semi-structured interview guide based on previously defined theoretical categories (Table 3). We used only two broad, open-ended guiding questions. We chose this approach because comprehensive questions encourage more reflective narratives, reduce response bias, and allow participants to define the contours of the phenomenon based on their own experiences. This method provides access to implicit dimensions, subjective perceptions, and attributed meanings, aspects often missed by overly structured instruments (Marconi & Lakatos, 2017). In this regard, data depth stems not from the number of questions, but from their capacity to elicit rich, detailed accounts. With the participants' consent, we audio-recorded and fully transcribed the interviews to ensure fidelity to the discursive content and enable detailed analysis.

We conducted systematic, non-participant observation, wherein one researcher monitored the organizational environment in situ without intervening. This technique captured behavioral elements, production routines, and organizational dynamics that frequently do not emerge in interviewees' discourse. We visited the four companies during previously defined periods (Company Alpha: March 11–14, 2025; Beta: March 24–27, 2025; Delta: April 7–10, 2025; Gamma: April 21–24, 2025), using a checklist as a guiding instrument. Concurrently, we employed document analysis as a complementary data source to contextualize and validate the evidence obtained from the interviews and observations. We examined internal organizational documents, including management reports, organizational policies, historical records, training materials, and strategic documents (Table 3). We collected these documents simultaneously with the field visits, enabling real-time data triangulation.

Table 3

Synthesis of the Collected Items

Categories	Question Guide	Checklist Observation	Document Review
Understanding Industry 4.0 Concepts	How does your company understand the concept of Industry 4.0 in the context of footwear manufacturing?	Employee training; an environment open to change and technological experimentation	Training materials or documents that explain the concept and its application in the company.
Practical Application of Industry 4.0 Components	What are the fundamental principles of Industry 4.0 that your company prioritizes most?	Available technological infrastructure; digitization of production processes; information flow between sectors; data traceability and monitoring	Strategies or plans that describe which actions are prioritized.

Source: Prepared by the authors.

To process the empirical corpus, we used content analysis as established by Bardin (2016). This process involved three stages: pre-analysis, material exploration, and result treatment. Pre-analysis consisted of organizing, preparing, and conducting an initial immersion in the corpus, which comprised full interview transcripts, field observation notes, and institutional documents. During this phase, we conducted a floating reading of the material.

Concurrently, we defined the thematic unit of analysis and the recording units. We explored the material through a hybrid coding process that combined a deductive approach (based on previously defined theoretical categories) and an inductive approach (emerging from the data). Initially, we performed open coding, identifying and labeling relevant segments with descriptive codes to preserve their proximity to the empirical content. Next, we conducted axial coding to organize these codes into the two analytical categories based on their interrelationships. To support this process, we used NVivo software, which enabled systematic coding, hierarchical category organization, and traceability among raw data, codes, and analytical inferences. This tool also allowed us to query and cross-reference sources (interviews, observations, and documents), thereby increasing analytical depth. This iterative process involved successive cycles of constant comparison among the data, codes, and literature, enabling the conceptual and empirical refinement of the categories.

In the final stage, we interpreted the categorized data to establish relationships between the empirical findings and the theoretical foundations. This analysis focused on identifying patterns, convergences, and divergences across cases, in accordance with the replication logic of multiple-case studies. To strengthen the reliability and validity of the results, we triangulated data and sources by comparing evidence from interviews, observations, and documents. Second, we applied analytical triangulation by comparing different interpretations of the data throughout the coding process. Additionally, the analytical process included peer review; the researchers who conducted this study discussed the categories, codes, and interpretations to reduce individual bias and increase interpretive consistency. Together, these procedures provide robustness to the content analysis process and support the validity of the resulting inferences.

4 ANALYSIS AND DISCUSSION OF RESULTS

This section presents the primary empirical results from an investigation of four small footwear companies, summarized in Table 4. Afterward, a table providing a comparative analysis across the cases, along with theoretical interpretations and implications.

4.1 Understanding of Industry 4.0 Concepts

I4.0 represents a model in which the integration of digital, physical, and organizational technologies redefines production processes and business models (Bibby & Dehe, 2018; Pagliosa et al., 2019). Nonetheless, the empirical data demonstrated that understanding of this concept still varied significantly among the analyzed companies, reflecting different stages of I4.0 maturity. Table 4 summarizes the empirical data for this category.

Table 4
Summary of Data on the Understanding of Industry 4.0 Concepts

Variables	Alpha	Beta	Gamma	Delta
Interviewee	E1: “automation and digitalization of production” to increase speed and precision. Recognizes that the topic remains “more in the realm of dreams than actually implemented.” E2: I4.0 is limited to the automation of repetitive tasks, although manual activities continue to predominate in the routine.	E3: “automation, connectivity, everything running automatically.” Acknowledges the distance from the business reality. E4: “a distant but necessary dream.”	E7: “the combination of digital and physical” to reduce waste and increase efficiency. E8: personalization and process optimization through real-time data integration.	E5: The concept is already integrated into the operation: “the factory begins to think for itself, data circulate in real time, and decisions become much faster and more precise.” E6: total integration of systems, processes, and people, focusing on efficiency and waste reduction.
Observation	Understanding is restricted to leadership, and the concept is associated with automation and digitalization. Employees are not familiar with it. No implementation plans were identified.	Managerial knowledge is present. No actions were identified, such as technical training focused on operations, effective use of I4.0 technologies in daily activities, or changes in production routines that reflected its principles.	Understanding is oriented toward concrete gains, such as greater production efficiency, product personalization, waste reduction, and customization.	Effective application of traceability, real-time monitoring, and intelligent integration among systems, such as IoT sensors, laser cutting with computer vision, and production control software linked to enterprise resource planning (ERP). Active participation of employees in the continuous improvement process.
Document Review	Internal presentation (Mar/2024) with a basic definition of the concept and its applications, as well	The analyzed training support document presents basic introductory definitions. It	Internal presentation: “Introduction to Industry 4.0 in Footwear Production” outlines the	Internal presentation material: “Industry 4.0 Workshop” defines Industry 4.0 as the

	as suggestions for automation in cutting and dashboards.	addresses technologies such as IoT, AI, Big Data, and cyber-physical systems, as well as the challenges faced by small- and medium-sized enterprises, including costs and qualifications.	company's specific objectives, such as waste reduction and order customization, and links the I4.0 pillars to the operational realities of the footwear sector.	integration of digital technologies, data, and people into an intelligent, sustainable, and collaborative production ecosystem.

Source: Prepared by the authors.

Table 5 presents a comparative analysis of maturity in understanding I4.0 among the investigated companies, which enabled the identification of analytical patterns.

Table 5
Comparative Analysis of the Understanding of Industry 4.0 Concepts

Commpany	**Level of Understanding**	**Main Characteristics**	**Analytical Pattern**
Alpha	Beginner	Concept restricted to leadership; lack of practical application	Initial conceptual recognition
Beta	Structured conceptual understanding	Managerial knowledge; low internal dissemination	Fragmented adoption
Gamma	Intermediate	Conceptual mastery with initial application	Progressive implementation
Delta	Consolidated	Integration between technology, people, and data	Systemic application

Source: Prepared by the authors.

The data reveal that understanding of I4.0 evolves from an abstract stage disconnected from practice (Alpha), through a phase of management-restricted adoption (Beta), to a partial, efficiency-oriented integration (Gamma), and ultimately to an integrated, operational level (Delta). These findings reinforce the premise that I4.0, as defined by Silva et al. (2019), Pacchini et al. (2019), and Pagliosa et al. (2019), is not limited to technological adoption but entails the integration of technical, organizational, and strategic dimensions. Company Alpha presents an incipient vision detached from practice, characterized by a management-restricted understanding and an absence of concrete implementation plans. This disconnection from immediate operational reality typifies the initial conceptual recognition stage described by Ghobakhloo and Iranmanesh (2018). This misalignment underscores a gap between declarative knowledge and operational capability; Company Alpha has not yet developed the organizational knowledge (intangible resources, as per Arantes et al., 2021) required to support rapid, flexible decision-making, thereby hindering its practical application.

In Company Beta, managers are familiar with the fundamentals of I4.0 (automation, data, connectivity), yet this knowledge remains confined to the conceptual level. The lack of internalization by teams and subsequent lack of practical application characterize a fragmented adoption, as discussed by Arcidiacono et al. (2022). This pattern revealed limitations in knowledge integration and dissemination capabilities, indicating low organizational digital maturity despite cognitive advances within the leadership. This evidence aligns with Hanauer, Schreiber, and Viana (2025), highlighting that the primary challenge lies in overcoming obstacles and limiting factors (e.g., high costs and managerial resistance).

Company Gamma represents an intermediate stage where knowledge begins to translate into practice, with initial applications focusing on efficiency and customization, albeit incrementally. Managers demonstrate a conceptual mastery of I4.0, interpreting it as the strategic integration of automation, real-time data, and digital technologies applied to production. This finding converges with Pacchini et al. (2019), who suggested that value creation in I4.0 occurs gradually as organizations develop the capabilities to integrate technologies and processes. This stage highlights the emerging role of dynamic capabilities (Al-Khatib et al., 2024), particularly in articulating strategy with operations.

Company Delta demonstrates a consolidated, applied understanding of I4.0, integrating data, personnel, and technologies in alignment with the vision of smart production ecosystems proposed by Pagliosa et al. (2019) and Elnadi and Abdallah (2024). Active employee participation in continuous improvement processes was identified, supported by concrete suggestions regarding technology use. This indicates the development of human resources and the knowledge fusion cited by Arantes et al. (2021). The use of autonomous systems (CPS, IoT) and big data analytics, as evidenced in Company Delta, reflects a shift in production toward a new benchmark of large-scale efficiency, as theorized by Hanauer, Schreiber, and Viana (2024). These observations confirm the proposition by Frank, Dalenogare, and Ayala (2019) that the value of I4.0 emerges from the integration of base and front-end technologies.

Across all companies, the results indicate that understanding I4.0 requires not only technical knowledge but also the absorptive capacity to translate this concept into concrete operational strategies tailored to each firm's specific context and production needs (Arantes et al., 2021). By empirically linking digital maturity with organizational capabilities, this study demonstrates that I4.0 adoption should be analyzed as a multilevel phenomenon wherein managerial cognition, organizational dissemination, and practical application develop interdependently, though not necessarily simultaneously. This evidence reinforces the need for theoretical models that are more sensitive to structural limitations and incremental trajectories of digital transformation, thereby broadening the comprehension of I4.0 beyond normative, technology-centric approaches.

4.2 Practical Application of Industry 4.0 Components

I4.0 is characterized by fundamental principles, including advanced automation, system integration, real-time capability, interoperability, decentralization, modularity, and virtualization (Gilchrist, 2016; Elnadi & Abdallah, 2024). Nevertheless, the level of understanding and application of these principles proves heterogeneous among the analyzed companies. Table 6 summarizes the data for this category.

Table 6
Synthesis of Data on the Practical Application of Industry 4.0 Components

Variable	Alpha	Beta	Gamma	Delta
Interview	E1: “if I had to choose one key principle, it would undoubtedly be automation” for the integration of production and inventory data. E2: desire to automate cutting and quality inspection.	E3 and E4: prioritization of the automation of repetitive tasks, digitalization of processes, and the need to integrate information across departments.	E7 and E8: focus on connecting machines to the management system and automating repetitive tasks, using data for rapid decision-making.	E5 and E6: complete integration of systems, including cutting, inventory, planning, and production, using real-time data for adjustments and personalization.
Observation	Principles mentioned only by leadership. Topics such as system integration and real-time data management were cited as desirable goals, but they remain far from the company’s reality.	Recurring discussions and growing concern among employees and managers regarding the repetitiveness of manual tasks and the fragmentation of information across departments. Discussions on the benefits of automation and data integration.	Automation of specific tasks in the finishing stage and the implementation of interconnected systems between the shipping and production departments, allowing automatic updates to order status. Use of spreadsheets integrated with the ERP system to monitor indicators, as well as regular meetings between departments to analyze operational data.	Autonomous operation of cutting and injection machines connected to the ERP, as well as the use of dashboards with real-time data, such as temperature and production pace, which operators use for immediate adjustments, eliminating manual records.
Document Review	Absence of formal records or structured plans for implementing I4.0.	The minutes of the internal meeting (February/2025) record the future integration of an ERP system and the gradual automation of operational tasks as goals.	2024 Digital transformation strategy report: prioritization of system integration and the development of an organizational culture receptive to new technologies.	The Internal Report “Industry 4.0 Roadmap” details system integration, automation goals, and actions focused on operational intelligence, including failure forecasting and automated reporting.

Source: Prepared by the authors.

Table 7 shows the different stages of I4.0 component application among the analyzed companies.

Table 7
Comparative Analysis of the Practical Application of Industry 4.0 Components

Company	Level of application	Empirical evidence	Analytical pattern
Alpha	Beginner	Discourse focused on automation; lack of implementation	Intention without operationalization
Beta	Preparatory	Discussions about automation and integration; operational concerns	Fragmented pre-implementation
Gamma	Intermediate	Specific automation; integration between sectors; use of enterprise resource planning	Modular implementation
Delta	Advanced	Integrated operation; real-time decisions; use of dashboards	Systemic application

Source: Prepared by the authors.

The results indicated that practical application did not occur linearly but progressively, conditioned by internal organizational factors along an adoption continuum. For example, the findings revealed an aspirational discourse (Alpha), a preparatory stage (Beta), structured yet partial initiatives (Gamma), and consolidated operational integration (Delta). These empirical data aligned directly with literature characterizing I4.0 as a set of structuring principles, including interoperability, virtualization, decentralization, and integration (Gilchrist, 2016; Elnadi & Abdallah, 2024), whose effectiveness depended on the organizational capacity for operationalization.

Company Alpha illustrated the initial digital maturity stage described by Ghobakhloo and Iranmanesh (2018), where the benefits of automation were recognized despite a lack of infrastructure and formal planning. However, I4.0 principles were only superficially recognized, emphasizing automation to reduce errors and increase productivity. This scenario highlighted the gap between strategic intent and operational practice, reinforcing the importance of tangible resources (technological infrastructure) identified by Arantes et al. (2021). The absence of concrete initiatives suggested a low level of technological absorptive capacity, limiting the transition from intention to action (Arantes et al., 2021).

In Company Beta, a clearer understanding of basic components emerged, featuring discussions on automation and data integration specifically linked to manual task inefficiency and information fragmentation. This stage paralleled the preparatory phase proposed by Frank, Dalenogare, and Ayala (2019), in which I4.0 design principles were recognized, but technical capabilities had not yet been developed. Operational tensions, such as rework and lack of system integration, acted as triggers for transformation; this corroborated Hanauer, Schreiber, and Viana (2025), who highlighted efficiency pressure as a driving vector for technological adoption.

Company Gamma followed a modular, progressive approach, prioritizing cultural acceptance and gradual integration across departments and systems through initiatives such as automating specific operational steps and integrating enterprise resource planning systems. This process was conducted cautiously, focusing on employee acceptance and internal training programs that reinforced the importance of digitalization. This incremental model aligns with Elnadi and Abdallah (2024), who emphasized the gradual development of digital maturity. Furthermore, it reinforced the proposition by Frank, Dalenogare, and Ayala (2019) regarding the coexistence of baseline technologies and operational applications. The emphasis on employee acceptance and internal capacity building evidenced the role of human resources and organizational capabilities (Arantes et al., 2021) as mediators of adoption.

Company Delta, in turn, represented an advanced stage, featuring real-time integration across machines, systems, and data (evidenced by dashboards and systems integrated with the enterprise resource planning), that reflected the smart operations model described by Elnadi and Abdallah (2024). This application level also aligned with the concept of smart factories (Arcidiacono et al., 2022) and the integration of enabling technologies, such as IoT and data analytics (Frank, Dalenogare & Ayala, 2019). Decentralized decision-making, where operators adjusted processes in real time, confirmed the transition toward a more autonomous, data-driven operational model (Monteiro et al., 2023).

Holistically, the results demonstrated that the practical application of I4.0 was conditioned by the articulation of strategic vision, technological infrastructure (tangible resources), and a receptive organizational culture (intangible resources) (Arantes et al., 2021). The literature has converged on the importance of these elements, yet tension persists between ideal integration models and the realities of small enterprises, which routinely face resource constraints, cultural barriers, and training challenges (Ghobakhloo & Iranmanesh, 2018; Al-Khatib et al., 2024). Thus, I4.0 adoption varied depending on internal capacities to overcome challenges (Hanauer, Schreiber, & Viana, 2025) and develop the necessary technological leadership (Arantes et al., 2021). Additionally, identifying distinct patterns (intention, preparation, modular implementation, and systemic application) helped refine the theoretical framework for I4.0 adoption stages, especially in the context of small businesses. This evidence challenged linear and universalist models, suggesting the need for approaches that are more sensitive to the contextual limitations of I4.0 as a complex, multifaceted organizational phenomenon.

5 CONCLUSIONS

This study aimed to investigate the conceptual understanding and practical application of fundamental Industry 4.0 principles and components in small footwear companies located in the Vale do Rio dos Sinos (Rio Grande do Sul), identifying variations in their digital maturity. To achieve this, a multiple case study was conducted across four small footwear enterprises in the Vale do Rio dos Sinos. Data triangulation was performed using semi-structured interviews with eight managers, systematic non-participant observation, and document analysis. Systematizing the results revealed varying levels of digital maturity regarding I4.0 incorporation among the investigated companies. In the “Understanding Industry 4.0 Concepts” category, Company Alpha presented an incipient view disconnected from practice, while Company Beta demonstrated theoretical managerial knowledge without internalization or practical application. In contrast, Company Gamma demonstrated a solid conceptual understanding at an initial application stage, and Company Delta showed a consolidated, applied understanding, reflecting the vision of smart, data-driven production ecosystems.

In the “Practical Application of Industry 4.0 Components” category, maturity differences were equally conspicuous. Companies Alpha and Beta remained in early stages, focusing on a desire for automation without translating this intent into technological infrastructure or concrete applications. Conversely, Companies Gamma and Delta demonstrated advanced stages: Gamma utilized a progressive approach focused on system integration and a receptive culture, whereas Delta closely patterned a smart operations model. The primary theoretical contribution of the study lay in explicating the dissociation between I4.0 understanding and its application. The findings demonstrated that digital maturity in small business contexts was better explained by an organization’s capacity to internalize knowledge than by isolated access to technology. The data indicated that I4.0 adoption should be understood as a multilevel process, in which organizational internalization, knowledge dissemination, and translation into functional practices depend heavily on leveraging specific organizational capabilities alongside digital maturity. Furthermore, digital maturity could not be treated as a static or binary construct; rather, it operated as a dynamic process mediated by capabilities such as resource absorption, integration, and reconfiguration. Additionally, the results suggested that hierarchical misalignment (between management and operations) acted as a critical barrier to the I4.0 transition, limiting the diffusion and effectiveness of digital initiatives.

Regarding managerial and practical contributions, the study provided a comparative diagnosis serving as a benchmark for small footwear enterprises, mapping the challenges and implementation stages of I4.0. The results indicated that leadership should focus not merely on purchasing technology but primarily on system integration, data quality management, and the development of an organizational culture capable of sustaining change (intangible resources). The evident gap between strategic discourse and operational practice reinforced the importance of strategies that promote integration between decision-making and operational levels.

Regarding limitations, this research focused on a small number of cases within a specific regional and sectoral context, restricting the broad generalizability of the results. Furthermore, the emphasis on a managerial perspective may not have fully captured operational dynamics and everyday resistance behaviors toward technological adoption. Therefore, future scientific research should expand the case study approach to include more companies and employ quantitative methods to empirically test the propositions offered here, especially concerning the relationship between organizational capabilities and digital maturity levels. Second, incorporating the perspective of operational employees is recommended to accurately unearth the mechanisms driving (or preventing) digital knowledge internalization. Lastly, comparative studies between traditional and technology-intensive sectors could help refine the general understanding of the implications of I4.0 adoption.

REFERENCES

Abicalçados – Associação Brasileira das Indústrias de Calçados. (2024). *Relatório setorial da indústria de calçados do Brasil 2024*. Abicalçados. https://www.abicalcados.com.br/publicacoes

Agolli, A., Kazani, I., Shehi, E., Spahiu, T., Hylli, M., Guxho, G., & Prence, E. (2025). Study on the application of digital technology in footwear industry in Albania. *Tehnicki Vjesnik – Technical Gazette,* 32(3), 1204–1209. https://doi.org/10.17559/TV-20241006002040

AL-Khatib A.W., Shuhaiber A., Mashal I., & Al-Okaily M. (2024), Antecedents of Industry 4.0 capabilities and technological innovation: A dynamic capabilities perspective. *European Business Review*, 36(4), 566–587. https://doi.org/10.1108/EBR-05-2023-0158

Allen, R. C. (2017). *The industrial revolution: A very short introduction*. Oxford University Press.

Arantes, R. C., Pereira, M. M. O., Castro, C. C., Mineiro, A. A. C., & Oliveira, J. A. (2021). A transformação digital e o conhecimento organizacional: Uma revisão sistemática da literatura. *Contextus – Revista Contemporânea de Economia e Gestão,* 19(21), 316–329. https://doi.org/10.19094/contextus.2021.71301

Arcidiacono, F., et al. (2022). The role of absorptive capacity in the adoption of smart manufacturing. *International Journal of Operations & Production Management*, 42(6), 773-796 https://doi.org/10.1108/IJOPM-09-2021-0615

Bardin, L. (2016). *Análise de conteúdo*. Edições 70.

Bibby, L., & Dehe, B. (2018). Defining and assessing Industry 4.0 maturity levels: Case of the defence sector. *Production Planning & Control,* 29(12), 1030–1043. https://doi.org/10.1080/09537287.2018.1503355

Büchi, G., Cugno, M., & Castagnoli, R. (2020). Smart factory performance and Industry 4.0. *Technological Forecasting and Social Change,* 150, 119790. https://doi.org/10.1016/j.techfore.2019.119790

Cavalcante, C. G. S., & Almeida, T. D. (2018). Os benefícios da Indústria 4.0 no gerenciamento das empresas. *Journal of Lean Systems,* 3(1), 125–151. https://www.aceguaratingueta.com.br/images/upload/files/META-2019_ACEG_ARTIGO_Os_benef%C3%ADcios_da_Ind%C3%BAstria_4.0_no_gerenciamento_das_empresas.pdf

Cucculelli, M., Dileo, I., & Pini, M. (2021). Filling the void of family leadership: Institutional support to business model changes in the Italian Industry 4.0 experience. *Journal of Technology Transfer,* 47(1), 213–241. https://doi.org/10.1007/s10961-021-09847-4

Culot, G., et al. (2020). The future of manufacturing: A Delphi-based scenario analysis on Industry 4.0. *Technological Forecasting and Social Change*. https://doi.org/10.1016/j.techfore.2020.120092

Demo, P. (2022). *Avaliação qualitativa*. Autores Associados.

Elnadi, M., & Abdallah, Y.O. (2024) Industry 4.0: critical investigations and synthesis of key findings. *Management Review Quarterly*, 74, 711–744 (2024). https://doi.org/10.1007/s11301-022-00314-4

Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics,* 210, 15–26. https://doi.org/10.1016/j.ijpe.2019.01.004

Gadre, M., & Deoskar, A. (2020). Industry 4.0 -Digital Transformation, Challenges and Benefits. *International Journal of Future Generation Communication and Networking,* 13, 139–149. https://www.researchgate.net/publication/344832176_Industry_40_-Digital_Transformation_Challenges_and_Benefits

Ghobakhloo, M., & Iranmanesh, M. (2018). Digital transformation success under Industry 4.0: A strategic guideline for manufacturing SMEs. *Journal of Manufacturing Technology Management,* 32(8), 1533–1556. https://doi.org/10.1108/JMTM-11-2020-0455

Gil, A. C. (2019). *Métodos e técnicas de pesquisa social* (7 ed.). Atlas.

Gilchrist, A. (2016). *Introducing Industry 4.0*. Springer. https://doi.org/10.1007/978-1-4842-2047-4_13

Governo do Estado do Rio Grande do Sul. (2025, novembro 17). *Em Novo Hamburgo, Gabriel Souza destaca ações do Estado para o setor coureiro-calçadista*. https://www.estado.rs.gov.br/em-novo-hamburgo-gabriel-souza-destaca-acoes-do-estado-para-o-setor-coureiro-calcadista

Hanauer, G. O., Schreiber, D., & Viana, L. P. (2024). Adoção de tecnologias da Indústria 4.0 para promover práticas sustentáveis. *Revista Alcance,* 31(3), 68–82. https://doi.org/10.14210/alcance.v31n3(Set/Dez).p68-82

Hanauer, G. O., Schreiber, D., & Viana, L. P. (2025). Tecnologias da Indústria 4.0 e seus impactos na operação sustentável das empresas. *Pretexto,* 25(4), 98–109. https://revista.fumec.br/index.php/pretexto/article/view/10357

Ietto, B., et al. (2022). The role of external actors in SMEs' human-centered Industry 4.0 adoption: An empirical perspective on Italian competence centers. *IEEE Transactions on Engineering Management*, 1–16. https://doi.org/10.1109/TEM.2022.3144881

Javaid, M., et al. (2020). Industry 5.0: Potential applications in COVID-19. *Journal of Industrial Integration and Management,* 5(4), 507–530. https://doi.org/10.1142/S2424862220500220Cited by:179

Jimeno-Morenilla, A., et al. (2021). Technology enablers for the implementation of Industry 4.0 in traditional manufacturing sectors: A review. *Computers in Industry,* 125, 103390. https://doi.org/10.1016/j.compind.2020.103390

Klingenberg, C. O., Borges, M. A. V., & Antunes, J. A., Jr. (2022). Industry 4.0: What makes it a revolution? A historical framework to understand the phenomenon. *Technology in Society,* 70, 102009. https://doi.org/10.1016/j.techsoc.2022.102009

Lakatos, E. M., & Marconi, M. A. (2017). *Fundamentos de metodologia científica* (8 ed.). Atlas.

Mahmood, T., & Mubarik, M. S. (2020). Balancing innovation and exploitation in the Fourth Industrial Revolution: Role of intellectual capital and technology absorptive capacity. *Technological Forecasting and Social Change,* 160, 120248. https://doi.org/10.1016/j.techfore.2020.120248

Marum, A. M., et al. (2022). Mudanças trazidas pela Indústria 4.0 para a área da engenharia mecânica. *Revista Científica SENAI-SP – Educação, Tecnologia e Inovação,* 1(1), 106–124. https://periodicos.sp.senai.br/index.php/rcsenaisp/article/view/8

Messeni Petruzzelli, A., Murgia, G., & Parmentola, A. (2022). How can open innovation support SMEs in the adoption of I4.0 technologies? An empirical analysis. *R&D Management,* 52, 615–632. https://doi.org/10.1111/radm.12507

Monteiro, G., Julião, J., & Gaspar, M. (2023). *Impacto da Indústria 4.0 no setor do calçado* (Dissertação de Mestrado). Católica Porto Business School. http://hdl.handle.net/10400.14/42409

Neumann, W. P., et al. (2021). Industry 4.0 and the human factor: A systems framework and analysis methodology for successful development. *International Journal of Production Economics,* 233, 107992. https://doi.org/10.1016/j.ijpe.2020.107992

Pacchini, A. P. T., et al. (2019). The degree of readiness for the implementation of Industry 4.0. *Computers in Industry,* 113, 1–8. https://doi.org/10.1016/j.compind.2019.103125

Pagliosa, M., Tortorella, G., & Ferreira, J. C. E. (2019). Industry 4.0 and lean manufacturing: A systematic literature review and future research directions. *Journal of Manufacturing Technology Management*, 31. https://doi.org/10.1108/JMTM-12-2018-0446

Silva, F., Julião, J., & Gaspar, M. (2019). *Impact of Industry 4.0 technologies in the Portuguese footwear industry* (Dissertação de Mestrado). Católica Porto Business School. http://hdl.handle.net/10400.14/29846

Singh, A., et al. (2023). Smart manufacturing systems: A futuristics roadmap towards application of Industry 4.0 technologies. *International Journal of Computer Integrated Manufacturing,* 36(3), 411–428. https://doi.org/10.1080/0951192X.2022.2090607

Wang, L., et al. (2020). What nurtures the Fourth Industrial Revolution? An investigation of economic and social determinants of technological innovation in advanced economies. *Technological Forecasting & Social Change,* 161. https://doi.org/10.1016/j.techfore.2020.120305

Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: State of the art and future trends. *International Journal of Production Research*, 56(8), 2941–2962. https://doi.org/10.1080/00207543.2018.1444806

Yin, R. (2015). *Estudo de caso* (5 ed.). Bookman.

CONTEXTUS
REVISTA CONTEMPORÂNEA DE ECONOMIA E GESTÃO

UNIVERSIDADE FEDERAL DO CEARÁ
FACULDADE DE ECONOMIA, ADMINISTRAÇÃO ATUÁRIA E CONTABILIDADE

CONTEXTUS
CONTEMPORARY JOURNAL OF ECONOMICS AND MANAGEMENT.
ISSN 1678-2089
ISSNe 2178-9258
1. Economics, Administration and Accounting - Journal
2. Federal University of Ceará. Faculty of Economics, Administration, Actuaries and Accounting

FACULTY OF ECONOMICS, ADMINISTRATION, ACTUARIES AND ACCOUNTING
University Av. – 2486, Benfica
60020-180, Fortaleza-CE
BOARD: Carlos Adriano Santos Gomes Gordiano
José Carlos Lázaro da Silva Filho

ADMINISTRATIVE AND PUBLISHING SUPPORT
Heloísa de Paula Pessoa Rocha (UFC)

Website: www.periodicos.ufc.br/contextus
E-mail: revistacontextus@ufc.br