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Advancing logistics digitalization through the Shingo 4.0 MIF: insights from a Brazilian footwear manufacturing case.

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Abstract: *This article applies the Shingo 4.0 – Material and Information Flow (MIF) approach to diagnose opportunities for digitalization in the order-fulfillment process of a Brazilian footwear manufacturer. The study is grounded in the need to address the company's low digital maturity, reflected in a low ERP activity rate of only 16.47%, a limited digital information access rate of 24.71%, and a very high dependence on non-digital and manual activities (Rate of Other Activities = 58.82%). These indicators reveal that most information is still exchanged through paper documents, operators' memory, or unintegrated media, which significantly compromises process reliability. Using an analytical case study design, the research mapped 85 operational activities, classifying them according to the Shingo 4.0 framework. The results show that 67.66% of the total lead time (85.467 minutes) is consumed by waiting activities, and 11.15% by inspections—both strongly associated with manual workflows, duplicated records, and the absence of integrated systems. The limited ERP use hinders data accuracy, delays approvals, and restricts real-time visibility, while the minimal use of digital media (e.g., spreadsheets and emails representing only 4 digital activities) prevents systematic monitoring of operational performance. The study concludes that the low digitalization rate amplifies waste, increases process variability, and obstructs decision-making. Strengthening digital integration—particularly through ERP–WMS connectivity, automated data capture, and standardized information flows—is essential for reducing lead times, improving traceability, and aligning the company with Industry 4.0 standards.*
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I. Introduction

Due to the evolution of manufacturing processes and the rapid succession of industrial revolutions, the world has increasingly embraced the concepts of Industry 4.0 across various sectors, aiming to enhance information integration through emerging digital technologies (Saidi & Soulhi, 2018). Given the highly competitive global environment in which companies operate, process digitalization has become essential and tends to grow in relevance as Industry 4.0 principles gain prominence. This transformation enables benefits such as reduced paper usage, fewer nonconformities, and improved operational efficiency, as processes become more integrated and less dependent solely on human expertise (Dantas et al., 2023). However, in countries such as Brazil, some organizations still face difficulties in implementing these innovations, primarily due to technological and structural limitations that hinder the adoption of Industry 4.0 practices (Vazquez, Silva & Sousa, 2024).

This case study was conducted in the shipping department of a company specialized in the production and commercialization of safety and occupational footwear. Founded in 2010 and located in the Vale do Sinos, Rio Grande do Sul—a region recognized as a national footwear hub—the company has consistently invested in quality, innovation, and technological advancement across its processes, products, and services. In this context, the Shingo 4.0 (MIF) approach becomes particularly relevant for mapping and identifying value-adding and non-value-adding activities within operational and production flows, thereby enabling the detection of waste and the proposal of improvements. Furthermore, the application of indicators reveals that information exchange occurs predominantly in an intuitive manner—often relying on operators' "memory"—highlighting a significant potential for improvement through digitalization and system integration (Shingo, 1988; Nunes et al., 2024).

This study therefore seeks to answer the following research question: How can opportunities for digitalization be identified within the order-cycle flow of a footwear company's shipping process? The main objective is to identify such opportunities using the Shingo 4.0 MIF approach. To achieve this goal, the following

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specific objectives were defined: (a) to map the current material and information flow; (b) to analyze the informational mechanisms supporting the flow; and (c) to propose a future-state model grounded in the digitalization of logistical processes. This manuscript is structured into six sections: (i) introduction; (ii) theoretical review addressing the digitalization of logistical processes (Woschank et al.,, 2021; Cuenca et al., 2020), order flow (Gois et al., 2023; Vivaldini et al., 2023), and Shingo 4.0 (MIF) (Shingo, 1988; Shingo & Dillon, 1989; Nunes et al., 2024); (iii) research methodology; (iv) case study presenting the context and results of the instantiation; (v) discussion, including interpretation of findings and digitalization proposals; and (vi) final considerations, outlining key insights and recommendations for improving the current flow.

II. Theoretical Review

2.1 Digitalization of Logistics Processes

The primary objective of logistics is to deliver the right product or service—in the appropriate quality, quantity, cost, time, and place. The notion of "right" may be defined either by customer requirements or by a company's strategic orientation. In essence, logistics concerns the movement of materials from suppliers to the firm, within the firm, from the firm to customers, and, when necessary, the return of products and/or materials. These flows encompass inbound logistics, internal logistics (intralogistics), outbound logistics, and reverse logistics (Woschank et al., 2021). These materials include all organizational inputs, whether tangible—such as raw materials, work-in-process items, finished goods, and spare parts or intangible, such as information, money, and knowledge (Waters, 2006).

Within these logistics' operations, two central flows exist: the material flow and the information flow. The former concerns the movement of physical items over time and space, whereas the latter encompasses the data and information required to enable material flows (Shingo, 1989; Nunes et al., 2024; Strassburguer et al., 2023). In the context of informational flows, Industry 4.0 contributes by integrating productive elements, information technology, and the internet. Known as the fourth industrial revolution, Industry 4.0 differs from earlier revolutions focused primarily on mechanical manufacturing processes and their organization—by extending its influence across the entire production and supply chain (Matt et al., 2020). Nevertheless, companies still show limited understanding of the digitalization opportunities specific to logistics (Woschank et al., 2021).

Beyond the physical flow, the information flow—often described as "the bloodstream of the supply chain" (Christopher, 2016)—is what ensures visibility, synchronization, and rapid responsiveness to fluctuations in demand or supply. Langley, Novack and Gibson (2023) emphasize that without accurate and timely data, inventory, transport, and production planning becomes mere conjecture; similarly, Bowersox et al. (2014) highlight that integrating orders, forecasts, production status, and transport events reduces uncertainty and enables economic lot formation consistent with real service-level requirements. Analysis of these flows begins with detailed mapping of information needs throughout the chain ("who needs what, when, and in what format"), followed by modeling the systems and documents that generate, transform, or store such data. Subsequently, metrics such as informational order-cycle time, master-data accuracy, electronic-document error rates, and decision lead time are applied—evaluated through process audits, KPI dashboards, or reference models such as SCOR. Comparing these metrics with strategic targets guides interventions in standardization, automation, and digitalization (Christopher, 2016), ensuring that Industry 4.0 innovations—such as IoT sensors, RFID, and real-time analytics—truly enhance logistical efficiency by converting raw data into actionable information delivered "at the right time and place" to support reliable, cost-effective operational and tactical decision-making.

A successful digital transformation requires clear process definitions, structured implementation phases, employee training, and standardized deployment procedures (Cuenca et al., 2020; Chiká & Nunes, 2024; Meudt et al., 2017). For logistics centers aligned with Industry 4.0, key criteria have been identified: intelligent handling, zero emissions (primarily transport-related), smart mobility, freight-exchange platforms, digital information platforms, intelligent transport systems, information security, real-time localization systems, logistics-center alliances, and digital connectivity (Yavas & Ozkan-Ozen, 2020). Among these, information security stands out as one of the most critical requirements for Logistics 4.0 systems to function effectively (Barreto et al., 2017).

Additional risks are also associated with Industry 4.0, beyond information security, including privacy concerns, trust issues, high investment and configuration costs, lack of technical skills and standardization, inadequate infrastructure, legacy-system modernization challenges, and resistance to change (Verma, Dixit & Kushwaha, 2020). Despite such challenges, evidence shows that IT-based systems improve the efficiency of receiving processes, order-fulfillment performance, inventory accuracy, and picking efficiency (Lee et al., 2018).

2.2 ***Order Flow***

Efficient management of information flow is essential for contemporary logistics, as it enables real-time monitoring of operations across the various sectors involved, while also facilitating effective control and proper data storage. The use of Business Intelligence tools has proven promising in this context, significantly contributing to operational visibility and to strategic, data-driven decision-making (Nascimento et al., 2024). In the industrial environment, this process encompasses the entire order cycle—from receipt to delivery—covering stages such as order processing, production, and shipping. The efficiency of this flow is fundamental for industrial competitiveness, particularly in the face of increasing consumer demands for customization and speed (Gois et al., 2023).

To meet these growing demands, emerging digital technologies have played a crucial role in transforming the logistics flow. Today, orders move through the logistics chain in diverse ways, driven by advanced technologies that significantly reshape supply-chain management. The integration of solutions such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, and automation has enabled greater visibility, efficiency, and adaptability in logistics operations (Chiká & Nunes, 2024). IoT sensors allow real-time tracking of goods, while AI algorithms optimize routes and forecast demand, resulting in a more responsive and resilient supply chain (Hofstatter, 2023). Moreover, the automation of warehouses and distribution centers—supported by robotics and intelligent systems—has reduced errors and increased productivity (Vivaldini et al., 2023). These innovations are central elements of the transition toward Logistics 4.0, characterized by the digitalization and interconnectivity of logistics processes.

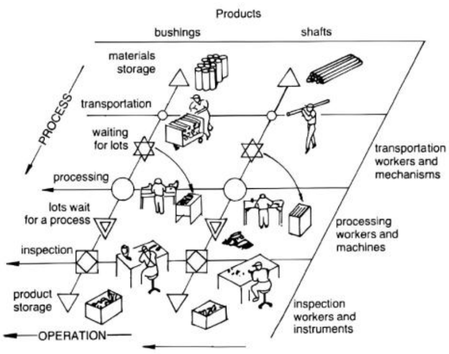
Building upon the digitalization of information flows, the implementation of cyber-physical systems has revolutionized real-time monitoring of industrial processes, providing increased visibility and control, directly impacting service quality. According to Müller et al. (2023), systems such as CyPhERS provide real-time situational awareness, enabling the identification and response to critical events in cyber-physical environments without relying on historical observations. Furthermore, Industry 4.0 not only optimizes the order flow but also drives continuous innovation within the production process. Fernandez-Caramés et al. (2024) highlight that integrating technologies such as unmanned aerial vehicles (UAVs) and blockchain into cyber-physical systems enables automated inventory control and traceability, reinforces cybersecurity, and supports advanced big-data analytics. These innovations are essential for competitiveness in the footwear industry and other industrial sectors.

2.3 Shingo 4.0 (MIF)

The approach known as Shingo 4.0—also referred to as MIF (Material and Information Flow) emerges from the need to integrate, in a detailed manner, the mapping of material flows and information flows with the foundational principles of the production mechanism proposed by Shingo (1988). This integration aims to comprehensively identify value-adding and non-value-adding activities within production and operational processes, thereby enabling the detection of waste and the proposal of continuous-improvement initiatives.

According to Shingo (1988) and Shingo and Dillon (1989), the principles underlying the Toyota Production System emphasize the importance of thoroughly mapping processes to reduce classic categories of waste—such as overproduction, unnecessary transportation, waiting, motion, inspection, and excessive processing. In the context of MIF, these concepts are expanded to include the informational flow, that is, how information is generated, transmitted, stored, and utilized throughout the production process. Through the mapping method proposed by Shingo and Dillon (1989), it becomes possible to identify, classify, and differentiate value-adding steps from those that constitute pure waste, thereby supporting targeted interventions within the flow (Figure 1).

Figure 1: Network of Operations



Source: Strassburguer et al., 2023.

This approach combines traditional material-flow mapping, as advocated by Shingo, with the concepts of VSM 4.0. Meudt et al. (2017) emphasize that this combination is important because it ensures that digitalization efforts are implemented based on a true understanding of the current process, allowing the identification of informational wastes that are not visible in traditional VSM (Rother & Shook, 1999; Silva et al., 2024). Existing value streams can be optimized through lean-production methods, while taking into account data flows that will later support digitalization and the implementation of Industry 4.0 solutions.

The Shingo 4.0 approach also details information flows and their associated performance indicators (KPIs). In this model, the analysis involves quantifying the *Activity Rate in ERP*, *Activity Rate Except ERP*, and the *Rate of Other Activities*. These metrics are essential to demonstrate that in environments where information exchange occurs predominantly through manual means—often relying on operators' memory—there is substantial potential for improvement through digitalization and system integration (Nunes et al., 2024; Santos et al., 2023).

Furthermore, the Shingo 4.0 methodology emphasizes the importance of considering not only informational tools (such as ERP systems, spreadsheets, and other digital platforms) but also non-human resources (equipment, documents, etc.). This holistic view allows the identification of bottlenecks not only in the physical execution of operations but also in informational exchanges, thereby facilitating corrective actions that contribute to reducing lead times and improving overall operational efficiency (Nunes et al., 2024).

The equations applied to understand the informational flows, as presented by Nunes et al. (2024), are divided into three factors: ERP activities, digitized activities except for ERP, and other activities. ERP activities group all the exchange of information using the ERP and its integrated modules (Equation 1). During process mapping, the data collected in this criterion will show how much information will be available to the company. Equation 4 is used to obtain this indicator.

$$Activity\ rate\ in\ ERP = \frac{\sum Information\ generated\ via\ ERP\ and\ integrated}{Total\ flow\ information} \quad (1)$$

Except for ERP, digitized activities are all in digital format but are not handled through the ERP and its integrated software. These are media such as spreadsheets and text editors (Equation 2).

$$Activity\ rate\ except\ ERP = \frac{\sum Information\ in\ which\ software\ not\ integrated\ with\ the\ ERP\ is\ used}{Total\ flow\ information} \quad (2)$$

The other activities consist of those actions carried out in the flow that are not exchanged by digital means and can be by memory or voice (Equation 3).

$$Rate\ of\ other\ activities = \frac{\sum Information\ that\ does\ not\ use\ digital\ means}{Total\ flow\ information} \quad (3)$$

In summary, Shingo 4.0 represents an evolution in process mapping, as it combines the robustness of the foundational principles of the Toyota Production System (Shingo, 1988; Shingo & Dillon, 1989) with the capabilities enabled by digitalization and the systematic use of performance indicators (Meudt et al., 2017; Nunes et al., 2024). This integration provides a holistic perspective that supports data-driven decision-making. Such a combination is particularly relevant in logistical and production environments, where the alignment between physical and informational flows is essential for maintaining competitiveness. The following section classifies this research and presents the methodological approach employed to address the central question of the study.

III. Methodology

The research conducted is applied in nature, as it encompasses context-specific interests and offers practical solutions to concrete problems. From the perspective of its objectives, the study is classified as exploratory—because it provides additional insights into the topic under examination—and descriptive, since the facts are recorded, analyzed, classified, and interpreted without interference from the researchers. Furthermore, the study is characterized as an analytical case study, aimed at collecting and examining information to investigate different aspects related to the research topic (Yin, 2002; Prodanov & Freitas, 2013). To carry out this study, a research method was developed.

Initially, the business organization selected as the object of study was chosen based on the authors' convenience as well as the relevance of the process to be mapped. The selected company specializes in the production and commercialization of safety footwear. The process chosen for analysis was the order receipt and consolidation process, as internal demands had indicated the need to improve its efficiency and enhance customer service agility. After defining the object of study, data were collected from the Commercial, Production Planning and Control (PPC), Shipping, and Financial departments. The data gathered included the duration of each activity, the informational medium used, the resources required for each task, the KPIs involved, and the individuals responsible for executing each step. Subsequently, the collected data were organized into an electronic spreadsheet, which enabled the initiation of the process mapping using the Shingo 4.0 approach to identify the current state. Traditional SPM calculations (Shingo, 1988; 1989) were then performed to determine value-added activities within the flow, along with the informational-flow calculations proposed by Nunes et al. (2024). Finally, the findings were analyzed based on the mapped consolidation and shipping flow.

The mapped flow encompasses all order-shipping activities up to final delivery to the customer. Activities were categorized into three groups, following Shingo (1988) and Nunes et al. (2024): value-adding (VA), necessary but non-value-adding (NNVA), and non-value-adding (NVA). Among the VA activities are loading and the issuance of fiscal documents; among the NNVA activities are order checking and document control; and among the NVA activities are waiting times, rework, and duplicate record entries.

The SPM reinforces the integrated analysis of material and information flows. It was observed that the process is heavily impacted by the lack of system integration, informal communication, and manual recordkeeping, all of which compromise process fluidity and information reliability. The analysis, grounded in Shingo's principles, revealed failures related to continuous flow, poor quality at the source, and insufficient standardization, which directly affect operational efficiency.

The improvement proposals guided by the method include record automation, integration of management systems (ERP and WMS), standardization of operational procedures, and enhanced employee training, all aimed at fostering an environment conducive to continuous improvement. Additionally, the indicators proposed by Strassburger—related to cycle time, rework, and digitalization—align with those used in the MIF approach (*Activity Rate in ERP, Activity Rate Except ERP,* and *Rate of Other Activities*), thereby strengthening the diagnostic analysis. Thus, the application of the SPM method complements the previously employed methodology and reinforces the alignment of the proposed solutions with lean manufacturing principles and Industry 4.0, serving as both a theoretical and practical reference for future analyses in administrative and logistical environments.

IV. Case Study

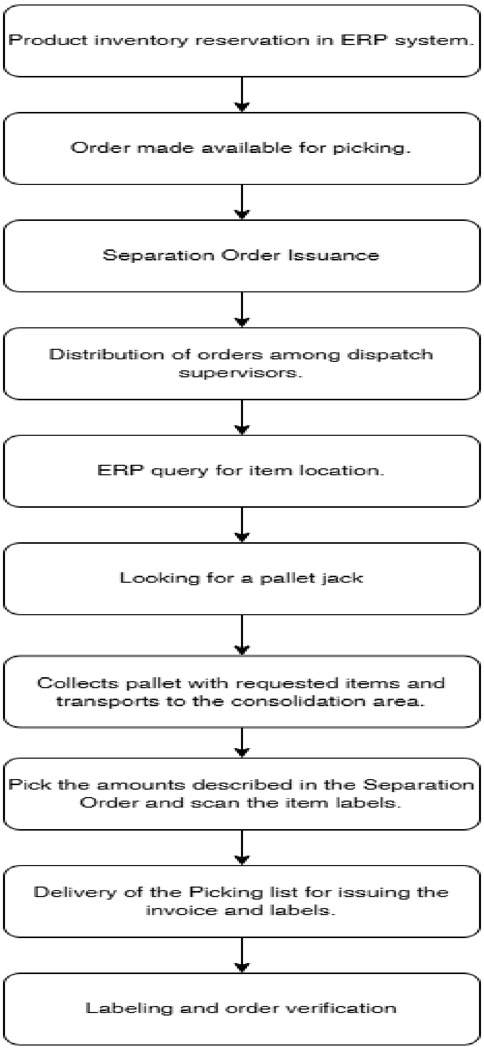
The object of this study is a footwear company located in southern Brazil. The organization operates under two production models—Make to Order (MTO) and Make to Stock (MTS) in order to ensure efficient inventory management and meet market demands while guaranteeing the strategic consumption of stocked products. The company records an average daily sales volume of 2,800 pairs of footwear, of which approximately 60% corresponds to items sold directly from finished-goods inventory. This sales flow was mapped using the methodology proposed by Shingo (Shingo & Dillon, 1989) and the MIF approach presented by Nunes et al. (2024) and Santos et al. (2023), requiring approximately 2.5 hours of dedicated analysis.

The selected flow is highly relevant to the company's operational environment, as it accounts for roughly 1,700 pairs shipped during an eight-hour work shift. Its importance is further reinforced by the fact that the remaining orders issued by the company follow similar workflows across the Commercial, Financial, and Fiscal departments.

4.1 Process Structure

The process begins with commercial activities, such as order analysis, stock verification, and entry of order data into the ERP system. This is followed by fiscal and financial checks, during which the customer's fiscal status is evaluated, and the order is formally approved. Once approved, the order proceeds to the Production Planning and Control (PPC) department, where products are reserved in stock for subsequent picking. After final approval, the Shipping department assumes responsibility for consulting the reserved orders, issuing the picking order, and distributing the picking documents to the operational team. This workflow is illustrated in the block diagram shown in Figure 2.

Figure 2 – Block diagram from order reservation to consolidation.



Source: Authors (2025).

As illustrated in Figure 2, the flow comprises all stages from stock reservation—performed through the ERP system—to consolidation in the shipping area, where label application and final order verification take place.

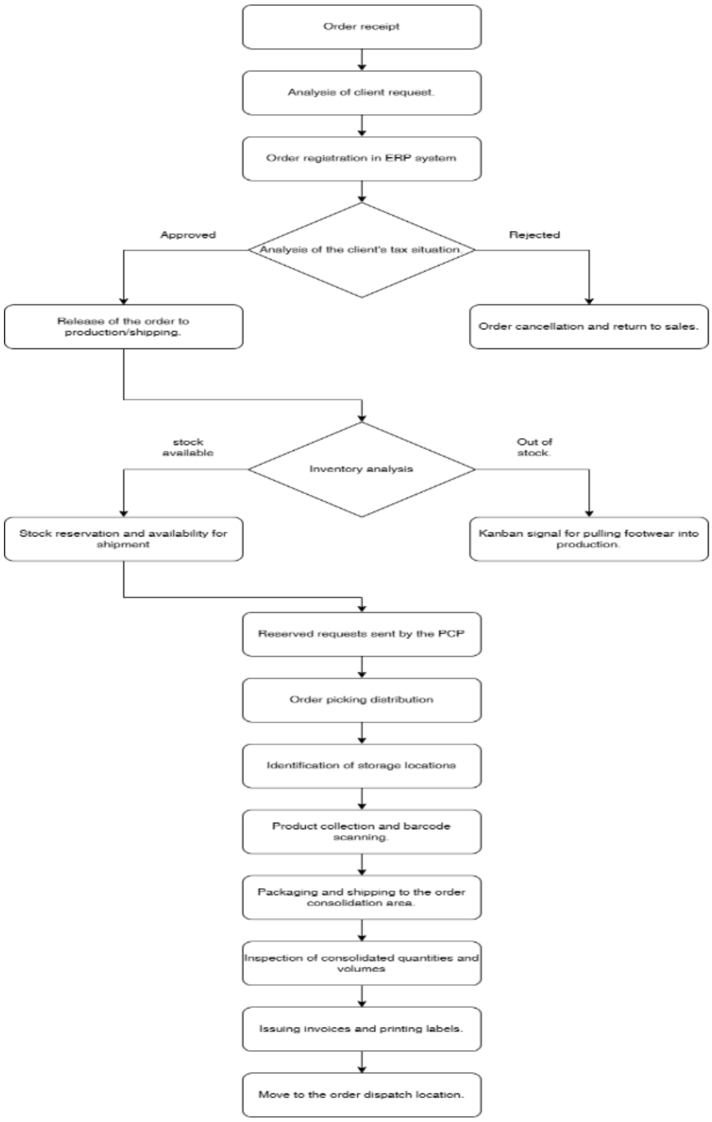
4.2 Execution of Picking and Storage

Shipping operators locate the required items using electric pallet trucks and consult storage spreadsheets organized in Microsoft Excel®. Barcode scanning of the packages is performed through the AT&M® ERP system, ensuring accurate product selection. Subsequently, the quantities picked are recorded manually for the subsequent verification stage. In addition to the picking activities, an internal transportation flow takes place, in which the products are moved to the consolidation and storage area. The process continues until all items belonging to the order have been correctly identified and their barcodes scanned. In the shipping area, orders are organized on pallets according to the customer and the designated carrier, allowing for subsequent issuance of fiscal documents and final dispatch.

4.3 Document Issuance and Final Shipping

Once the picking process is completed, the next stage involves issuing the fiscal invoice, with all information validated in the ERP system. The printing and application of identification labels ensure full traceability of the order. Following this, the products are transported to the shipping area and prepared for dispatch to the customer. The entire workflow is illustrated in Figure 3.

Figure 3: Operational order flow



Source: Authors (2025).

From Figure 3, it is possible to observe the workflow beginning with order receipt and continuing through to the movement of goods to the shipping area. The following section presents the results and discussion, which analyze the flow and apply the corresponding indicators.

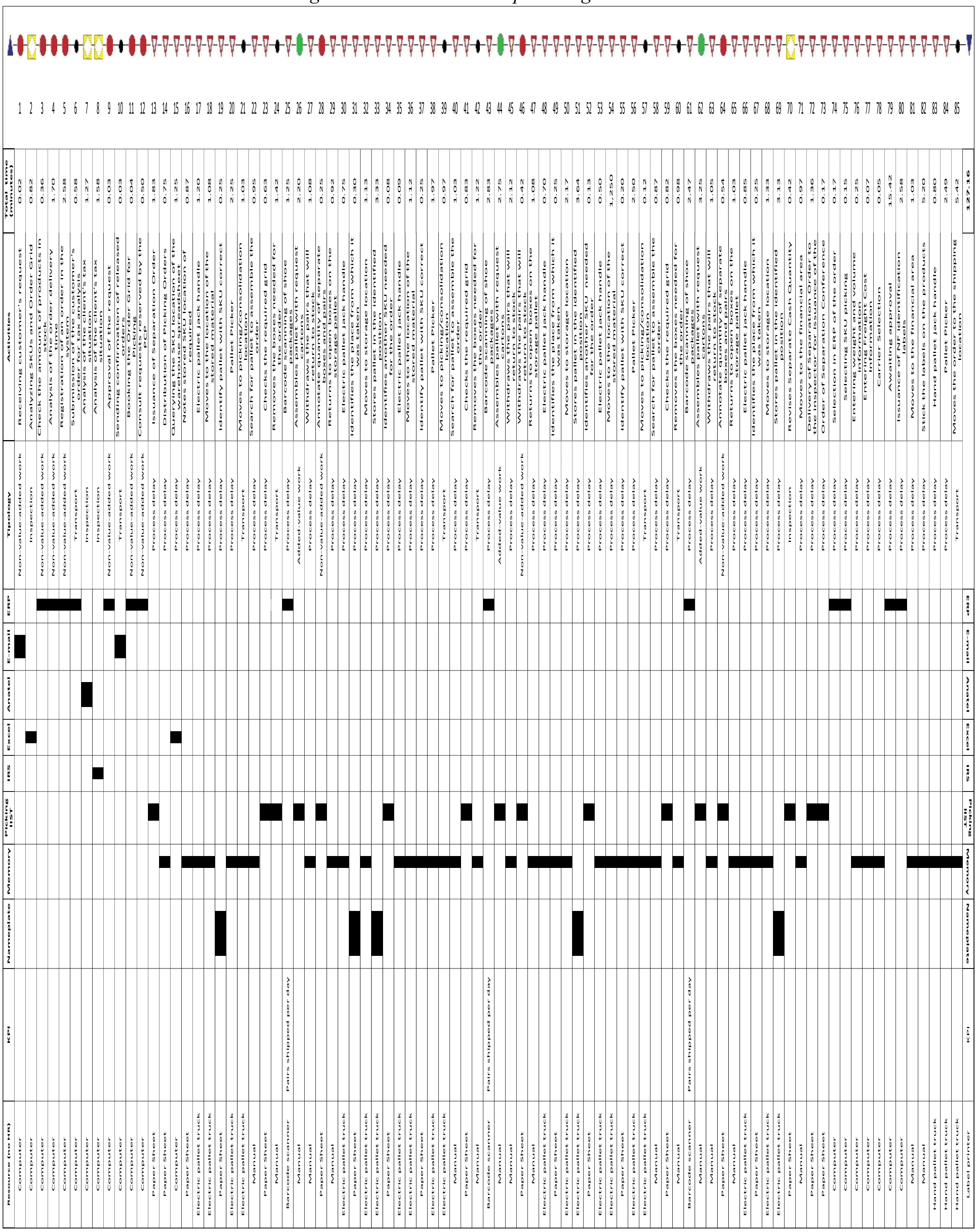
4.4 Return and Storage of Items in Inventory

After the requested items have been picked according to the Picking Order, any unopened packages of finished products that will not be used are sealed and returned by the operator to their previously recorded storage locations, as noted on the picking list.

4.5 Results

The value stream map was developed based on the definitions shown in Figure 5, which were selected according to the symbology proposed by Shingo. The application of Shingo's notation (Shingo, 1988; 1989) and Nunes et al. (2024) makes it possible to visualize the processes and classify their nature within the workflow, distinguishing those that do not add value. The complete process mapping is presented in Figure 4.

Figure 4: Value stream map – Shingo 4.0



Source: authors (2025)

4.5.1 Sequence of Activities in the Value Stream Map

The mapped process comprises 85 activities, beginning with the receipt of the customer order and ending with the movement of the order to the shipping area, as illustrated in Figure 6. The activities were organized in a logical sequence that reflects the actual operational flow and were classified according to the Shingo 4.0 methodology.

The chronological order of the main stages—highlighting the departments involved, the resources used, and the nature of the activities (VA, NNVA, or NVA) is as Figure 4.
The activities were mapped using seven distinct data sources: e-mail, Excel, ERP, Anatel and IRS websites, picking lists, employees' memory, and identification labels. The predominance of manual resources—such as paper (14.12%) and electric pallet trucks (24.71%) highlights the low digital maturity of the process.

4.5.2 Main Performance Indicators

According to the tools presented by Nunes et al. (2024) and Meudt et al. (2017), it is possible to map and analyze both information and material flows. The total lead time identified—127.167 minutes—includes processing time, waiting time, and inspection time, revealing clear opportunities to reduce non-value-adding time. Analysis of the dependence on ERP systems and manual processes indicates that technological integration could significantly improve shipping performance (equations 4 and 5).
Value-Adding Time (VAT):

$$\%\,AV = \left(\frac{8.2}{127.167}\right) x\ 100 = 6.44\% \qquad (4)$$

Non–value-adding activity time (NNAV):

$$\%\,NNAV = \left(\frac{118.967}{127.167}\right) x\ 100 = 93.56\% \quad (5)$$

Activity rate in ERP

Activity rate in ERP measures the proportion of activities that capture data automatically and digitally. In the case under study, the following informational media were used: the ERP system (digital and automatic) in 14 activities; Excel spreadsheets (digital, but not integrated or automatic) in 2 activities; and e-mail (digital, but not integrated or automatic) in 2 activities—totaling 85 activities in the analyzed flow (equation 6).

$$Activity\ rate\ in\ ERP = \frac{\sum Information\ generated\ via\ ERP\ and\ integrated\ (14)}{Total\ flow\ information\ (85)} = 16.47\% \quad (6)$$

Activity rate except ERP

The Activity rate except ERP measures the proportion of activities in which information is captured through traceable (though not fully integrated) systems, rather than through the ERP. In the case analyzed, these consisted of: (i) Excel (digital, but neither integrated nor automatic) – 2 activities; (ii) e-mail (digital, but neither integrated nor automatic) – 2 activities; and (iii) online consultations (digital, but neither integrated nor automatic) – 2 activities (equation 7).

$$Activity\ rate\ except\ ERP = \frac{\sum Information\ in\ which\ software\ not\ integrated\ with\ the\ ERP\ is\ used\ (6)}{Total\ flow\ information\ (85)} = 7.05\% \quad (7)$$

Rate of other activities

The analysis reveals that the company exhibits a high *Rate of Other Activities*, relying heavily on non-digital informational media: (i) operator memory – 44 activities; (ii) picking orders (paper) – 16 activities; and (iii) identification tags (paper/visual) – 5 activities (e.g., sequences 7, 19, 21). This substantial dependence on manual processes—evidenced by the extensive lack of integration between the ERP system and the operational flows—indicates significant operational inefficiency, increased waste, and limited real-time decision-making capability, positioning the organization at a low level of maturity with respect to Industry 4.0 (equation 8).

$$Rate\ of\ other\ activities = \frac{\sum Information\ that\ does\ not\ use\ digital\ means\ (65)}{Total\ flow\ information\ (85)} = 76.47\% \quad (8)$$

Information access rate

It measures the extent to which information is available through digital means. Accordingly, the use of Excel (digital, but neither integrated nor automatic) in 2 activities, the use of e-mail (digital, but neither integrated nor automatic) in 2 activities, the execution of online consultations (digital, but neither integrated nor automatic) in 2 activities, and the performance of 15 activities through the ERP informational medium result in a total of 21 activities with digital access to information. For the calculation of the *information access rate*, the following equation was applied (equation 9).

$$Information\ access\ rate = \frac{\sum System\text{–}Related\ Information\ (21)}{Total\ flow\ information\ (85)} = 24.70\% \quad (9)$$

Information use rate
A Information use rate mede a proporção de atividades que geram KPIs utilizáveis para gestão: Atividades com "Nome KPI" preenchido: 3 atividades (leitura de código de barras) and atividades sem KPIs: 82 atividades (sem campo preenchido ou com memória/papel) (equation 10).

$$Information\ use\ rate = \frac{\sum of\ the\ information\ collected\ that\ generate\ KPIs\ (3)}{Total\ flow\ information\ (85)} = 3.52\% \qquad (10)$$

The Information Use Rate measures the proportion of activities that generate KPIs that can be used for managerial purposes. In the case analyzed, only 3 activities contained a filled "KPI Name" field (barcode scanning), whereas 82 activities had no associated KPIs (either with no field completed or relying on memory/paper).

Table 1: Distribution by Type

Wastes	Time (minutes)	Cumulative Frequency	% Cumulative
Process delay	85.467	85.467	67.66%
Inspection	14.083	99.55	11.15%
Transport	12.983	112.533	10.28%
Added-value	8.2	120.733	6.49%
Non-added-value work	6.433	127.166	5.09%

Source: Authors (2025).

The analysis of Table 2 identifies the main sources of waiting time, which total 85.467 minutes. *"Awaiting approval"* is the most significant contributor, with 15.417 minutes (18.04%), followed by *"Stores pallet in the identified position"* (10.1 minutes, 11.82%). *"Pallet picker"* (8.85 minutes, 10.36%), *"Barcode scanning of shoe packages"* (6.55 minutes, 7.66%), and *"Stick the labels on the products"* (5.2 minutes, 6.08%) complete the five largest losses, together accounting for approximately 53.96% of all waiting time. These activities reveal inefficiencies in manual approvals, storage operations, and traceability procedures.

Table 2: Distribution of Process Waiting Times

Activity	Time (min)	%	% Cumulative
Awaiting approval	15.4	18%	18.04%
Stores pallet in the identified position	10.1	11.82%	29.86%
Pallet Picker	8.9	10.35%	40.21%
Barcode scanning of shoe packages	6.6	7.66%	47.87%
Stick the labels on the products	5.2	6.08%	53.96%
Electric pallet jack handle	4.8	5.66%	59.61%
Moves to storage location	4.6	5.42%	65.04%
Withdraws the pairs that will return to stock	4.3	4.97%	70.01%
Moves to the location of the stored material	3.5	4.04%	74.04%
Returns to open boxes on the storage pallet	3.0	3.55%	77.59%
Search for pallet to assemble the order	2.9	3.33%	80.93%
Issuance of NF identification labels	2.6	3.02%	83.95%
Checks the required grid	2.3	2.67%	86.62%
Moves to the finance department	2.0	2.34%	88.96%
Issuance of Picking list	1.8	2.15%	91.11%
Delivery of picking list to the inspector for issuance of the invoice	1.4	1.60%	92.71%
SKU location query storage spreadsheet	1.3	1.46%	94.17%
Notes stored location of SKU required	0.9	1.01%	95.18%
Notes stored location of required	0.8	0.94%	96.12%
Hand pallet jack handle	0.8	0.94%	97.06%

Picking list distribution	0.8	0.88%	97.93%
Identify pallet with correct SKU	0.7	0.82%	98.75%
Entering weight and volume information	0.3	0.29%	99.04%
Identifies another SKU required for the order	0.2	0.25%	99.30%
Picking list conference	0.2	0.20%	99.49%
Selection in ERP of the order	0.2	0.20%	99.69%
Selecting the recovered SKUs	0.2	0.18%	99.86%
Entering freight cost information	0.1	0.08%	99.94%
Carrier selection	0.1	0.06%	100.00%

Source: Authors (2025).

The analysis of Table 3 reveals the predominance of manual and analog resources, with the electric pallet truck leading at 21 activities (24.71% of the total), followed by computer use and manual operations, each with 18 activities (21.18%). The use of paper, present in 12 activities (14.12%), and paper/visual media, in 8 activities (9.41%), highlights the dependence on non-digital methods. Digital resources—such as the barcode scanner (3 activities, 3.53%), computer/Excel, and computer/printer (1 activity each, 1.18%) appear only marginally, underscoring the low digitalization of the process, which is further evidenced by an ERP utilization rate (*activity rate in ERP*) of only 16.47%.

Table 3: Distribution of resources excluding human labor

Type	Time (min)	Cumulative frequency	% Cumulative
Electric pallet truck	21	21	24.71%
Computer	18	39	21.18%
Manual	18	57	21.18%
Paper	12	69	14.12%
Paper/visual	8	77	9.41%
Barcode reader	3	80	3.53%
Hand pallet truck	3	83	3.53%
Computer/MS excel	1	84	1.18%
Computer/Printer	1	85	1.18%

Source: Authors (2025).

Process waiting times dominate the flow, accounting for 67.66% of total time (85.467 minutes), followed by inspections (11.15%, 14.083 minutes), transport (10.28%, 12.983 minutes), processing (6.49%, 8.2 minutes), and necessary but non–value-adding activities (5.09%, 6.433 minutes).

The electric pallet truck is directly associated with transport activities—such as movements toward consolidation—and with process waiting, such as pallet storage. The intensive use of paper and paper/visual resources contributes to necessary non–value-adding activities, such as manual recording of quantities, and to administrative waiting, such as grade verification. The computer, although a digital resource, is linked to long delays, particularly in invoice issuance, while the barcode scanner appears in barcode-reading tasks, which constitute a significant waiting activity. Collectively, these resources reflect the 78.81% of non-productive time**,** composed of delays and inspections, indicating that manual management and physical handling represent the primary bottlenecks.

It was observed that the activity *"awaiting approval"* in the Fiscal/Financial department consumes 15.417 minutes (18.04%), followed by *"stores pallet in the identified position"* (10.1 minutes, 11.82%) and *"pallet picker"* (8.85 minutes, 10.36%) in the Shipping department. *"Barcode scanning of shoe packages"* (6.55 minutes, 7.66%) and *"stick the labels on the products"* (5.2 minutes, 6.08%) also contribute significantly. The electric pallet truck is central to waiting associated with storage and movement, representing 22.18% of total waiting time when *"stores pallet"* and *"pallet picker"* are combined. Paper, used in grade checks (2.283 minutes) and picking list issuance (1.833 minutes), reinforces analog management practices, while the computer—predominant in approval procedures—is the single largest contributor to waiting. The barcode scanner, although present for data capture, is underutilized, resulting in unrealized digital potential.

The integration of these data demonstrates that inefficiencies in the shipping process are rooted in the high dependence on manual resources—such as electric pallet trucks and paper—and in the underutilization of digital tools, such as barcode readers. The predominance of delays (67.66%) and inspections (11.15%) is amplified by these resources, which sustain slow, error-prone processes. ERP approval, dependent on computer-based processing, and pallet-truck movements emerge as the principal bottlenecks, while paper-based management contributes to the low digitalization rate observed.

V. Discussion of the Results

The analysis of the order and shipping flow, conducted through the Shingo 4.0 MIF approach, revealed improvement opportunities that align directly with the concepts presented in the theoretical review—particularly those related to the digitalization of logistics processes, the management of order flows, and the application of the Shingo 4.0 model. The results reinforce the importance of integrating physical and informational flows to eliminate waste and enhance operational efficiency, as advocated by Shingo (1988) and Shingo and Dillon (1989).

As highlighted by Woschank et al. (2021), digitalization in industrial logistics is essential for ensuring visibility, synchronization, and responsiveness to fluctuations in demand. However, the mapping revealed that 67.66% of the total lead time (85.467 minutes) is consumed by process waiting, such as *"Awaiting approval"* (15.417 minutes) and *"Stores pallet in the identified position"* (10.1 minutes), demonstrating a strong dependence on manual procedures and a low level of integration between systems such as the ERP and Excel spreadsheets. These findings corroborate Cuenca et al. (2020), who emphasize that digital transformation requires well-defined processes, training, and standardization—elements notably lacking in the analyzed flow, where ERP utilization is only 16.47%**.** The predominance of analog resources, such as paper (14.12% of activities) and employees' memory (44 activities), reflects the technological and structural limitations in Brazilian companies identified by Vazquez et al. (2024), which hinder full adoption of Industry 4.0 principles.

The low information-use rate (3.53%) aligns with Christopher's (2016) characterization of informational flow as the "bloodstream" of the supply chain. The absence of integrated and traceable data compromises decision accuracy and timeliness, as noted by Langley, Novack, and Gibson (2023), resulting in inefficiencies such as rework and excessive inspections (11.15% of lead time). Technologies such as IoT and cyber-physical systems, suggested by Fernandez-Caramés et al. (2024), could mitigate these bottlenecks by enabling real-time tracking and automated inventory control, thereby aligning the process with the principles of Logistics 4.0 described by Yavas and Ozkan-Ozen (2020).

Efficient management of the order flow, as discussed by Gois et al. (2023), depends on cross-departmental integration and operational visibility. The study revealed fragmentation among the Commercial, PPC, Fiscal/Financial, and Shipping departments, with a heavy reliance on manual records such as paper-based picking lists (16 activities). This scenario contradicts the need for synchronization emphasized by Bowersox et al. (2014), who highlights the importance of integrating orders, inventory, and transportation to reduce uncertainty. Only 14 of the 85 informational flows are connected to the ERP system, which increases lead time, particularly in stages such as tax approval (18.04% of all waiting time).

These results reinforce the relevance of emerging technologies, as noted by Chiká and Nunes (2024), who emphasize the role of AI and Big Data in route optimization and demand forecasting. The underutilization of the barcode reader (3.53% of activities) contrasts with the potential for real-time traceability described by Vivaldini et al. (2023), indicating that the adoption of systems such as WMS could significantly enhance the picking and consolidation processes (Chiká & Nunes, 2024).

The Shingo 4.0 approach, as originally proposed by Shingo (1988) and later expanded by Meudt et al. (2017) within the VSM 4.0 context, was essential for classifying activities as value-adding (VA), non–value-adding but necessary (NNVA), and non–value-adding (NVA). The mapping revealed that 78.81% of total time is consumed by non-productive activities**,** such as waiting and inspections, corroborating Shingo's (1988) emphasis on eliminating waste, including unnecessary transportation and waiting. The analysis of informational media, as described by Nunes, Chiká, and Santos (2024), highlighted that low digitalization and weak system integration perpetuate bottlenecks, such as the intensive use of electric pallet trucks (24.71% of activities) and paper-based methods, both of which contribute to inefficiencies in transportation (10.28% of lead time) and administrative management.

Shingo's SPM (Strassburger et al., 2023) further complemented the analysis by reinforcing the need for standardization and automation, aligning with Shingo's principles of continuous flow and quality at the source. The identification of failures—such as rework during order verification—reflects the lack of standardization noted by Santos et al. (2023). The improvement proposals, including ERP–WMS integration (Nunes et al., 2024) and employee training, resonate with Barreto et al.'s (2017) view on the importance of digital connectivity for logistical efficiency, underscoring the need to align the process with Industry 4.0 standards.

In summary, the results obtained reinforce the effectiveness of the Shingo 4.0 MIF approach in diagnosing inefficiencies and proposing data-driven improvements, as advocated by Shingo and Dillon (1989).

The strong dependence on manual processes and the low level of digital maturity—evidenced by the indicators—reflect the challenges discussed by Verma et al. (2020) regarding the implementation of Logistics 4.0. The integration of digital technologies and the standardization of processes are fundamental steps toward reducing waste, improving traceability, and aligning the company with the principles of Industry 4.0, thereby enhancing competitiveness in the footwear sector.

VI. Final remarks

This study aimed to map and analyze the material and information flow within the shipping department of a footwear company, with the objective of identifying digitalization opportunities through the Shingo 4.0 approach. The results demonstrated that this methodology can serve as a powerful tool for diagnosing and proposing improvements in logistics processes, particularly in industrial environments that still exhibit low levels of digital integration. The mapping of the order flow revealed a significant predominance of non–value-adding activities, many of which are sustained by manual practices and analog resources such as paper, spreadsheets, and operator memory–based consultations.

The analysis of informational indicators showed that only a small fraction of activities is effectively automated and integrated into management systems. This finding reinforces the urgent need for investment in technology and automation to eliminate waste, reduce waiting times, and enhance operational efficiency. The proposed digitalization of the logistics flow—supported by data and structured mapping—demonstrates that consistent improvements can be achieved through system integration, automation of repetitive tasks, and the adoption of real-time information. In this regard, technologies such as barcode readers, interconnected ERP systems, and well-defined operational indicators become essential to sustain competitiveness and innovation in the footwear sector.

It is concluded that digital transformation, more than a trend, constitutes a strategic necessity for companies seeking to improve their logistical performance and meet market demands with agility and accuracy. The Shingo 4.0 MIF methodology proved effective in providing a systemic view of the process, guiding data-driven decision-making and fostering more efficient, lean, and Industry 4.0–aligned management. This study focused on mapping the order flow within the shipping sector of a single footwear company, with specific attention to the application of the Shingo 4.0 MIF approach. This scope allowed for an in-depth analysis of a representative process but limits the generalizability of the results to other sectors or industries.

Additionally, the data were collected within a specific time frame and based on the practices in place at the moment of the study, which may not reflect subsequent changes or improvements. Another limitation concerns the absence of a direct assessment of the impacts of the proposed improvements after implementation. Future research should replicate the methodology in other sectors of the same company or in organizations of different sizes and industries to compare levels of digital maturity and validate the method's applicability in diverse contexts. Longitudinal studies are also recommended to track the effectiveness of actions implemented based on the diagnostic results, evaluating their impact on performance indicators over time.

The findings of this study offer relevant contributions to managers and professionals involved in process management and improvement. The application of the Shingo 4.0 MIF approach proved effective in identifying operational bottlenecks and measuring the degree of digitalization in logistics flows, providing concrete support for decision-making. For process managers and engineers, the integrated analysis of material and information flows enables the prioritization of interventions based on objective data, promoting greater operational efficiency. The use of informational indicators allows continuous monitoring of digital maturity across processes. Moreover, the technique proposed by Nunes et al. (2024) reinforces the importance of mapping and standardizing activities, guiding initiatives aimed at automation and system integration. In this way, the technique contributes to aligning organizational processes with the principles of Industry 4.0, supporting continuous improvement and innovation strategies.

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