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The impact of warehouse management systems (WMS) and digital technologies on inventory accuracy and operational efficiency in distribution centers: a systematic literature review.

The impact of warehouse management system (WMS) and digital technologies on inventory operational accuracy and efficiency in distribution centers: a systematic literature review

The impact of the warehouse management system (WMS) and digital technologies on inventory precision and operational efficiency in distribution centers: a systematic review of the literature

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SUMMARY

Warehouse Management Systems (WMS) have been widely adopted in Distribution Centers as a strategy to increase operational efficiency and inventory accuracy. Objective: To analyze, through a Systematic Literature Review (SLR), the impact of WMS and associated digital technologies on inventory accuracy and operational efficiency in Distribution Centers. Method: SLR conducted in the Web of Science, Scopus, and SciELO databases, covering publications from 2009 to 2026, following the PRISMA 2020 protocol.
Thirty-four articles were selected after screening by relevance score, reading titles and abstracts, and full reading with support from the Elicit platform. Results: WMS integrated with RFID consistently increases inventory accuracy to 98%–99.8%, with significant reductions in processing times and a substantial decrease in labor costs. The greatest gains occur in operations that migrate from manual systems to integrated platforms. WMS implementation represents a consolidated strategy for modernizing logistics operations, with positive impacts on efficiency, accuracy, and service level, conditioned on the technological and organizational readiness of the facility.

Keywords: warehouse management system; WMS; RFID; IoT; inventory accuracy; operational efficiency; Distribution Centers; production engineering.

ABSTRACT

Warehouse Management Systems (WMS) have been widely adopted in Distribution Centers to improve operational efficiency and inventory accuracy. Objective: To analyze, through a Systematic Literature Review (SLR), the impact of WMS and associated digital technologies on inventory accuracy and operational efficiency in Distribution Centers. Method:
SLR conducted in Web of Science, Scopus, and SciELO, covering 2009–2026, following PRISMA 2020 protocol. Thirty-four articles were selected after relevance score screening, title/abstract reading, and full-text analysis supported by the Elicit AI platform. Results: WMS integrated with RFID consistently increases inventory accuracy to 98%–99.8%, with expressive reductions in processing times and substantial decreases in labor costs. The largest gains occur in operations that transition from manual systems to integrated platforms. WMS implementation is a consolidated strategy for modernizing logistics operations, with positive impacts on efficiency, accuracy, and service level.
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1 INTRODUCTION

The increasing complexity of logistics operations, driven by the expansion of e-commerce and the demand for higher levels of customer service have made it... Inventory accuracy is a critical performance indicator. Inventory discrepancies generate direct impacts on operational costs, replacement planning, service level and in the financial results of organizations (BALLOU, 2009). To meet this challenge, the Warehouse Management Systems *(WMS)* have been widely adopted as a technological solution that integrates receiving processes, Warehousing, order picking and shipping.

The literature shows that the association of WMS with identification technologies automatic, such as radio frequency identification (RFID) And the Internet of Things (IoT) enhances operational gains by providing visibility. real-time monitoring of material flows, reducing reliance on manual processes. subject to errors. However, gaps still persist in the understanding of the moderating factors of results, organizational barriers, and the performance of these technologies in different Installation profiles (ZHEN; LI, 2022; MINASHKINA; HAPPONEN, 2023b).

Given the above, this work is guided by the following research question: what It is the impact of WMS and associated digital technologies on inventory accuracy and on How is operational efficiency in distribution centers affected? The overall objective is to analyze this impact by... through RBS. The specific objectives are: to identify the main digital technologies associated with WMS and its mechanisms of impact on inventory accuracy; mapping the operational efficiency results reported in the literature; identify the requirements organizational and technological aspects for effective implementation; and to identify the main challenges and Barriers to WMS adoption in distribution centers.

From the perspective of Production Engineering, the topic directly connects the fields of operations management, quality management, continuous improvement, and industrial automation (CORRÊA, 2017). This article is organized into five sections: theoretical framework, methodology, results and discussion, and final considerations.

2 LITERATURE REVIEW

The theoretical framework is organized into three pillars that support the analysis of

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Results: warehouse logistics, Warehouse Management Systems (WMS) and technologies digital associations.

2.1 Warehouse Logistics

Business logistics encompasses all activities related to planning, execution and control of the efficient flow of goods and information, from the point of view of originating from the end consumer, with the aim of meeting customer demands in the shortest possible time. total cost (BALLOU, 2009). In this context, Distribution Centers (DCs) have evolved from Support structures for key strategic assets in the supply chain, playing a role decisive in the speed of service and in reducing logistics costs (MOURA, 2006).

Discrepancies between system records and physical inventories result in stockouts. Supply, costly excesses, and accounting discrepancies that compromise the financial and operational efficiency of organizations (CORRÊA, 2017). According to Assaf Neto (2014), the Inventories make up a significant portion of current assets, and inadequate inventory control can lead to problems. It compromises both liquidity and organizational profitability.

2.2 Warehouse Management System (WMS)

Warehouse Management Systems (WMS) are technological platforms. Developed to plan, control, and optimize the internal operations of warehouses and centers. Distribution. By integrating the physical control of inventory movements with digital records. In real time, the WMS enables complete traceability of items throughout the entire supply chain. Storage management, from receiving to shipping, eliminating record gaps, sources primary inventory discrepancies (ZHEN; LI, n.d.).

The main functionalities of WMS include: address control and product location, receiving and merchandise verification management, routing guided for order picking and packing, rotational and cyclical inventory control, Integration with automatic reading devices, and generation of reports and indicators of Operational performance. These features contribute to the elimination of errors. Humans and to increase the reliability of inventory records, connecting directly related to the principles of Continuous Improvement and Total Quality Management (TQM) widely studied in Production Engineering (CORRÊA, 2017).

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2.3 Digital Technologies Associated with WMS

The effectiveness of WMS is enhanced by integration with technologies such as Automatic identification and connectivity, which together make up the ecosystem of Logistics 4.0. RFID enables the simultaneous reading of multiple items without the need for a production line. Direct line-of-sight contact between reader and tag enables real-time inventory and traceability. continuous without interruption of operations (RUQNUZZAMAN et al., 2026).

The Internet of Things (IoT) expands the ecosystem by connecting sensors and devices. and systems in integrated networks for collecting and transmitting data in real time, increasing the Operational visibility and control of material flows in distribution centers (PERERA et al., 2023). According to Hermann, Pentek and Otto (2016), the convergence of these digital, physical and Biological technologies define the Industry 4.0 paradigm, which directly impacts asset management and... production systems.

Emerging technologies, such as computer vision with neural networks. Convolutional computing, autonomous robots, and RFID are at the forefront of warehouse automation. Daios and Kostavelis (2024), in a broad survey on technologies in distribution centers, They cataloged more than twenty solutions applied to internal logistics, confirming the acceleration of automation process in the sector. Ekren et al. (2026) call this stage Warehousing. 5.0 a paradigm that positions human-machine collaboration, sustainability and well-being. to be central pillars of modern logistics systems, in line with the concept of Industry 5.0 described by Maddikunta et al. (2022).

3. RESEARCH METHOD

This article adopted the Systematic Literature Review (SLR) methodology. a structured approach focused on the careful location, evaluation, and synthesis of studies. relevant to a given topic, defined as a structured and replicable protocol. to map, critically evaluate, and synthesize the scientific knowledge produced. (COMFORT; AMARAL; SILVA, 2011). This methodological choice is justified by the nature Research question: What is the impact of WMS and associated digital technologies on... How does inventory accuracy and operational efficiency affect distribution centers? Given the scope... To achieve the desired answer, the decision was made to map the reliable literature of scientific production in order to... To present synthesized and relevant results.

Regarding its nature, this is qualitative research, which seeks to understand the

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phenomena in depth, considering the context and the interpretation of meanings present in the literature analyzed (MINAYO, 2001). This approach is consistent with the problem This research is based on the research for this study, as the impact of WMS is not a measurable phenomenon. This study does not directly address this issue, but rather the systematic interpretation and synthesis of existing evidence. produced by the scientific community. Regarding its objectives, it is classified as exploratory and descriptive (GIL, 2017): exploratory, because the research problem investigates a field A rapidly evolving technological landscape, for which there is still no consolidated synthesis in the context. Brazilian; descriptive, because it seeks to systematically map and characterize the impacts, requirements, challenges and technologies associated with WMS, directly addressing the objectives. specifics derived from the research question.

3.1 Review Protocol

The review protocol was recorded and managed using the StArt software. (Systematic Review Support Tool), to support the conduct of systematic reviews of literature, as suggested by Fabbri et al. (2016). The process of selecting and reporting studies followed the guidelines of the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA), a set of international guidelines developed to ensure Transparency, quality, and reproducibility in systematic reviews (PAGE et al., 2021). The steps are described in detail below: i) identification and screening of sources; ii) data extraction from Items included.

3.2 Identification of information sources and screening

The identification of articles was carried out in the Web of Science and Scopus databases. and SciELO. The generic search string applied was: TITLE-ABS-KEY((Warehouse Management System* OR WMS) AND (improvement* OR efficiency OR challenge* OR requirement* OR automation) AND (distribution center* OR warehouse*) AND (RFID OR barcode OR IoT OR robot* OR identification technology)). Searches returned 1,351 Raw records: 246 in Scopus, 562 in Web of Science, and 543 in SciELO.

To clean up the 1,351 articles, formal inclusion criteria were established and Exclusion. Regarding the inclusion criteria, the articles considered eligible were those that were reviewed. peer review, master's dissertations, and undergraduate theses that presented explicit methodology; publications in Portuguese and English; studies that

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They analyzed the practical use of WMS in physical storage contexts or in centers of distribution; and the work that demonstrated improvements in productivity, technical requirements, challenges or interactions with technologies associated with WMS.

Regarding the exclusion criteria, opinion articles were discarded. commercial, editorial, and conference abstracts lacking methodological detail; studies that They approached WMS solely from the perspective of software development, without Physical application in a storage environment; work in areas unrelated to the topic. such as health, agriculture and mining; and duplicate records that have not been deleted. automatically during the import phase in the StArt software.

After applying the exclusion criteria, a filtering workflow was adopted. as defined by Fabbri et al. (2016), to select relevant articles. The workflow of Filtering was conducted in three sequential phases, with irrelevance removed by scoring. (score). In the first phase, the StArt *scoring* tool was used to rank the studies by Relevance based on frequency and combination of search equation terms in the fields. of title, abstract, and keywords. The records with the least thematic adherence were archived, which resulted in the selection of the 50 studies most aligned with the theme for the eligibility phase. In the second phase, the 50 studies were submitted to screening by title and Summary with application of eligibility criteria. In the third phase, the approved studies were submitted to full reading with support from the Elicit platform, resulting in the corpus. The final selection consisted of 34 articles. The PRISMA flowchart of the selection process is presented in Figure 1.

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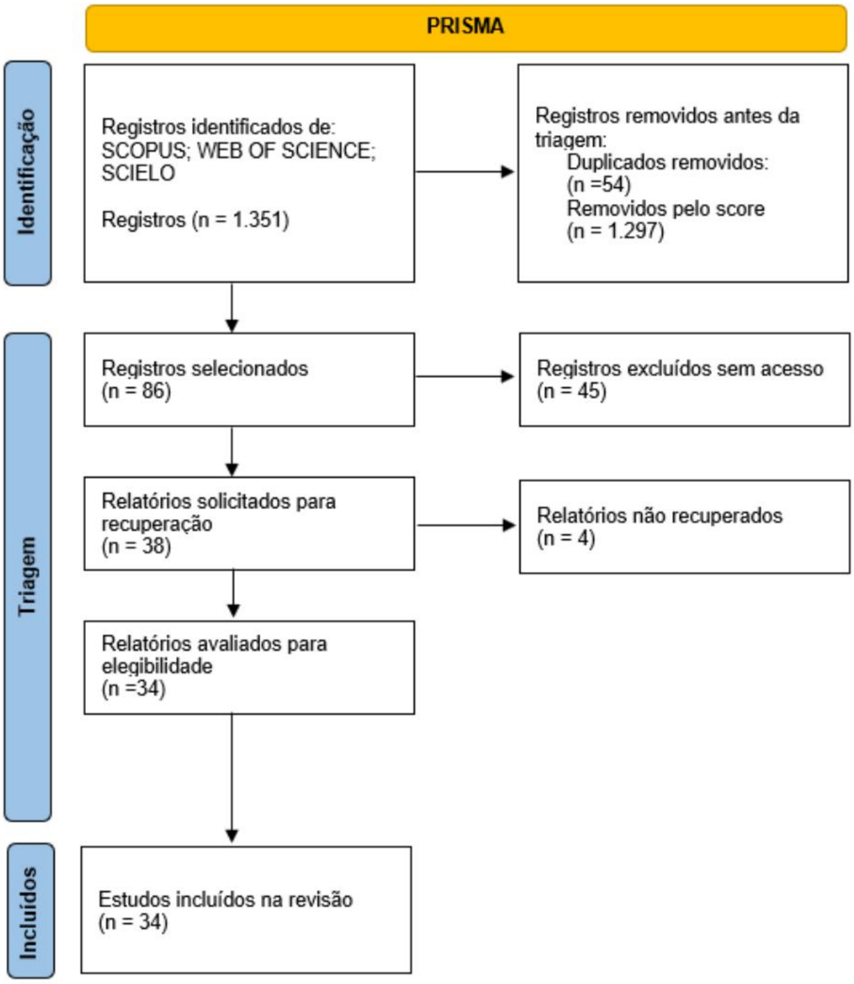

Source: author's own elaboration.

3.3 Data Extraction from Included Articles

The 34 selected articles were processed on the *Elicit platform.* This tool Artificial intelligence was developed to automate and accelerate review processes. systematic literature review (AKTAY, 2024). The platform was parameterized to respond to Extraction questions from Table 2, directly linked to the specific objectives of this work. The questions were formulated in English for compatibility with the processing. linguistic aspects of the platform. All results generated by the tool were confirmed by Manual reading during data extraction for each article.

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Extraction Question Code (English / Portuguese)		Corresponding objective
QE1	What operational improvements or benefits does the WMS provide? What operational improvements or benefits does WMS provide?	OE-b: mapping efficiency results
QE2	What problems or difficulties does the WMS face? What problems or difficulties are faced by WMS?	OE-d: raising challenges and barriers
QE3	What automation systems are used with the WMS? What automation systems are used with WMS?	OE-a: identify technologies
QE4	What is the main conclusion about WMS performance or implementation? What is the main conclusion regarding the performance or implementation of the WMS?	General summary
QE5	Does the study report a measurable result? (accuracy rate, error reduction, cycle time) Does the study present a measurable result? (accuracy rate, error reduction, cycle time)	OE-b and OE-a: evidence of impact

Table 2 — Elicit parameterized extraction questions and corresponding specific objectives

4. RESULTS AND DISCUSSION

The research comprises 34 studies published between 2009 and 2026. predominantly empirical articles that adopt the case study or experimental design. as a methodology, complemented by systematic literature reviews. The discussion is structured in five sections that follow, in the same order, the defined extraction questions. in the methodology.

4.1 WMS Improvements

The analysis of the studies identified two central areas for improvement: efficiency. Operational aspects of warehouse processes and inventory accuracy.

Operational efficiency is the most consistently documented benefit in The studies analyzed manifested themselves in three interrelated dimensions: significant reduction. reduced processing time, lower labor costs, and improved utilization of installed capacity. The greatest gains are observed in studies that combine RFID with process redesign. Chen et al. (2013) reported a significant reduction in total time.

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operation by integrating RFID with Lean Manufacturing practices and cross-docking in a Center of Distribution.

Zhang (2025) documented significant reductions in processing times of Entry, inventory counting, and product exit after barcode migration. for RFID, with a substantial simultaneous reduction in labor costs. Hehua (2021), in A simulation study in an e-commerce company demonstrated that passive RFID... significantly reduced waiting times in both the storage and processing phases. Item reconfirmation, with a positive impact on order completion rates. Wang et al. (2010) reported that the same facility that significantly reduced staff of The increased loading significantly expanded the utilization of the warehouse's capacity. establishing a net gain in systemic productivity, a result consistent with the The perspective of OEE (Overall Equipment Effectiveness), widely used in Engineering. Production systems (SLACK; BRANDON-JONES; JOHNSTON, 2018). Systems based on IoT improvements, as reported by Hamdy et al. (2022) and Jarašÿnienÿ et al. (2023), have been documented. substantial in the accuracy of demand forecasting and the efficiency of order processing, demonstrating that IoT adds a predictive dimension to WMS that goes beyond simple traceability.

The improvement in inventory accuracy is the most robust and consistent finding of this study. review. Unlike reductions in processing time, which show good Variability depending on the context, accuracy results converge to a pattern. Common and predictable, regardless of sector, country or size of operation: all studies Those who compared scenarios before and after implementation reported a significant increase in Accuracy after adopting a WMS integrated with RFID. Table 3 qualitatively summarizes this. the findings of the main studies.

Study	Technology	Pre-level WMS	Post-level WMS	Qualitative observation
Wang et al. (2010)	RFID-DWMS	Low	High	Greatest absolute gain — operation started with manual control.
Zhang (2025)	RFID	Low	High	Barcode vs. RFID comparison in large-scale operation.
Jarašÿnienÿ et al. (2023)	IoT, cloud	Moderate	Elevated	Ceiling effect — baseline already digitized beforehand
Fu et al. (2023)	Passive RFID	Not informed	High	Accuracy of counting and stock-taking in a factory environment.
Kong et al. (2024)	RFID + R-CNN	Not reported	High	Integrating computer vision with RFID for of

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				recognition

Table 3 — Qualitative summary of the impacts of WMS on inventory accuracy
Source: author's own elaboration.

This convergent pattern has a technical explanation, identified by Iorga et al. (2026): passive UHF RFID read rates have a natural practical limit, determined by environmental factors such as electromagnetic interference, orientation of labels and shadow zones, which sets a performance ceiling for this technology in Real-world operating conditions, regardless of the industry context or the size of the facility.

This convergence has direct implications for the management of working capital assets in distribution centers. According to... According to Assaf Neto (2014), inventories comprise a significant portion of current assets and their Inadequate control compromises both liquidity and organizational profitability. Implementing a WMS integrated with RFID drastically reduced discrepancies. inventory, with a direct impact on financial planning and customer service levels (CORRÊA, 2017). Alherimi et al. (2024), in a systematic review on approaches to Optimization in digital warehousing has confirmed that technologies such as AGVs, IoT, and robots... Collaborative spaces increase space utilization and reduce total operating costs, reinforcing the direction of the findings of this review.

4.2 Difficulties Faced by the WMS

Leadership engagement is a recurring critical factor in studies. Vatumalae et al. (2022) demonstrate that organizational readiness, which includes managerial engagement, Team training and process redesign prior to implementation are crucial. Regarding the technology adopted, Minashkina and Happonen (2023) report implementation cycles. WMS timeframes range from 3 to 30 months, with staggered releases as a best practice.

Atieh et al. (2016) demonstrated, in a case study in the telecommunications sector In Jordan, the implementation of automated WMS completely eliminated errors. Labeling reduced dependence on third-party labeling services, resulting in cost savings. The automation of data capture. However, the quality of pre-existing registration data. (SKUs, addressing, and movement history) This is an indispensable prerequisite. Kmiecik (2022), in an analysis of 29 3PL distribution networks, confirms that the consistency of data is the factor that correlates most strongly with the accuracy results obtained, in in accordance with the principle of quality control at the process input, as already warned Correa (2017).

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The installation cost is the main barrier to WMS adoption. especially for small and medium-sized enterprises, which face *a considerably longer payback period. longer compared to large operations; the literature shows a scarcity of Formal return on* investment analyses, with Kuÿera (2017) being one of the few exceptions with documented data (JARAŠÿNIENÿ et al., 2023). The technical limitations of RFID constitutes the second category, with emphasis on electromagnetic interference of metal structures, sensitivity to label orientation, and the occurrence of zones of shadow, factors that establish a natural performance limit for the technology in real operating conditions (IORGA et al., 2026; CHEN et al., 2013). Integration with Legacy systems constitute the most persistent technical barrier in operator contexts. third-party logistics (3PL) providers, where incompatibility arises between the platforms used by customers and partners make it difficult to implement integrated solutions (MINASHKINA; HAPPONEN, 2023).

4.3 Automation Systems Used with WMS

Studies show a technological progression that goes from identification From automatic to full physical automation, organized into four distinct generations. RFID is the automation system most frequently integrated with WMS in the corpus, present in more than 15 out of 34 articles. Its operation is based on reading radio frequency tags, without The need for a direct line of sight allows for the automatic capture of data from multiple sources. items simultaneously. Poon et al. (2009) developed one of the first integrated systems of logistics resource management, based on RFID and case-based reasoning (R-LRMS), demonstrating that automating the formulation of picking solutions can reduce significantly reduces order preparation time in industrial environments. The code of Bars, in turn, remain relevant as a lower-cost and more mature solution. being frequently combined with RFID during technological transition phases (ZHANG, 2025; KUÿERA, 2017). Hidayah and Priambodo (2023) demonstrated that the application of readers RFID in a WMS system significantly reduced item identification errors in comparison with the manual process, reinforcing the superiority of radio frequency over conventional methods, even in smaller-scale operations.

IoT represents the second layer of automation identified in the studies. Adding predictive capabilities to the WMS through sensor networks that monitor continuously monitor warehouse conditions. Hamdy et al. (2022) proposed an IoT system.

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Based on Node-RED and MongoDB, capable of integrating sensor data into the WMS in real time. Ruqnuzzaman et al. (2026) confirm, in a systematic review of 107 articles, that the IoT sensor networks represent the main frontier of innovation in intelligent management. warehouses.

Kong et al. (2024) integrate RFID into convolutional neural networks for the recognition and automatic product location, demonstrating that the combination of Radio frequency and computer vision provide superior identification capabilities compared to... each technology in isolation. This convergence between RFID and AI connects to the paradigm of Industry 4.0 as described by Hermann, Pentek, and Otto (2016). Mancini et al. (2023) investigated the A chipless variant of RFID that eliminates the integrated circuit from the tags, reducing substantially lower the unit cost, as an alternative for price-sensitive operations. Although Although the results indicate technical feasibility, the technology is still in the phase of... prototyping and lacks validation on an industrial scale. Ekren et al. (2026) introduce the The concept of Warehousing 5.0, which envisions the integration of collaborative robots and systems of... Automated storage and retrieval systems and autonomous guided vehicles integrated with the WMS. Operating on low-latency 5G networks, aligned with Maddikunta's Industry 5.0 concept. et al. (2022).

4.4 WMS Performance

The synthesis of the studies' conclusions reveals three predominant lines of thought. The first is that the implementation of WMS represents a structural transformation in Logistics operations: Chen et al. (2013) and Wang et al. (2010) conclude that WMS eliminates It identifies systemic sources of waste and enables a completely new warehouse management model. distinct from the manual model. The second concluding point is that the operational context moderates The results: Jarašÿnienÿ et al. (2023) and Minashkina and Happonen (2023a) conclude that facilities with a lower technological baseline achieve the greatest relative gains, while Operations that are already partially digitized show more modest improvements. The third line emphasizes that a standalone WMS is not enough: its effectiveness depends on integration with identification technologies, ERP systems and aligned organizational practices (YANG; YAN, 2023; RUQNUZZAMAN et al., 2026).

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4.5 Operational Impact on the Studies Analyzed

The analysis identified that the dominant type of evidence is case studies with Comparison before/after WMS implementation, in a single installation, without a group of control. This approach, while providing direct and contextualized empirical evidence, It presents methodological limitations for causal attribution of results, since changes simultaneous in the warehouse reorganization process, in team training and in Redesigning the layout can contribute to the observed gains independently of... technology (BASHATAH; ELNAGGAR, 2025).

Of the studies analyzed, the vast majority present evidence of descriptive in nature, with reports of improvement based on observation and direct comparison, without application of formal statistical validation instruments. Only one study (BASHATAH; ELNAGGAR (2025) adopted an experimental design with formal methodological rigor, obtaining consistent and statistically proven improvements, albeit of a smaller magnitude than compared to other studies. This contrast highlights a significant methodological gap in the field: Studies with greater formal rigor tend to report more modest impacts, while The most significant results lack standard statistical validation, which should be considered in Interpretation of the findings of this review.

CONCLUSIONS

This systematic literature review analyzed 34 studies published between 2009 and 2026, with the goal of understanding the impact of WMS and associated digital technologies. in inventory accuracy and operational efficiency in distribution centers.

WMS integrated with RFID consistently improves inventory accuracy. for 98%–99.8%, regardless of sector, country, or size of operation. This effect The ceiling is technically explained by the read rates of passive UHF RFID, which define... Mathematically, the practical limit achievable. Significant reductions in times of Processing improvements are achievable in operations migrating from manual systems to RFID. integrated into process redesign, with the greatest gains occurring when technology and the Lean Manufacturing is combined. The factor that most determines the magnitude of the results. It is the technological maturity of the previous baseline, not the sophistication of the technology adopted. Organizational factors, such as leadership support, data quality, and integration with ERP systems are just as crucial to success as the technology itself.

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