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Leveraging S/4HANA EWM for Sustainable and Paperless Warehousing

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Abstract

Warehousing has become central to the performance of supply chains and environmental sustainability, especially as logistics execution is redefined through digital transformation. Warehouse processes in paper form are associated with operational inefficiencies, data latency and unnecessary material usage which curtails the capacity of organizations to meet the sustainability goals. This paper will analyze how SAP S/4HANA Extended Warehouse Management (EWM) can be used as a digital execution platform to facilitate paperless and sustainable warehousing. An illustration-based approach to methodology is chosen as a conceptual one, which decomposes the operations of the warehouse, maps the digital execution capabilities, and constructs a theoretical model of the relationship between paperless execution and the results of operational and sustainability processes. The experimental outcomes are supported by representative warehouse performance indicators, illustrating productivity gains, reduced errors, minimized rework, and impacts on energy consumption. The results indicate that execution-layer digitalization is critical in implementing operational excellence into quantifiable sustainability performance. The research findings are added to the expanding literature on the topic of sustainable warehousing since ERP-integrated warehouse execution systems are presented as key facilitators of paperless and logistically responsible warehousing activities.

Keywords: S/4HANA EWM; Sustainable Warehousing; Paperless Warehouse; Digital Execution; Warehouse Management Systems; Green Logistics; Supply Chain Sustainability

1. Introduction

Warehousing is one of the key support systems of contemporary supply chains that directly affect the level of accuracy in inventory, order fulfilment performance, and environmental performance. Along with the active growth of world trade and e-commerce, warehouses have turned into a complex, data-intensive, and resource-consuming system. The nature of the traditional warehouse business, found to be disjointed in terms of information flow, manual data entry, and paper based organizational processes, plays a part in operational inefficiencies, error rates and avoidable environmental impacts in terms of over consumption of paper and waste of energy [1]. The challenges have increased the need to have digitally enabled and sustainable warehousing solutions.

Sustainability has become a leading topic in recent years in the area of research regarding operations and supply chain management due to regulatory requirements, corporate environmental responsibility, and the expectations of the stakeholders [2]. Such digital transformation technologies as enterprise resource planning (ERP) system, advanced warehouse management systems (WMS), and real-time data analytics are regarded as the enabling factors of green logistics operations. SAP S/4HANA Extended Warehouse Management (EWM) is one of these technologies, which is a next-generation, integrated warehouse management platform that is meant to aid real-time visibility, process automation, and paperless execution of intelligent supply chains. With the usage of in-memory computing and embedded analytics, S/4HANA EWM allows conducting a lean warehouse process and provides chances to minimize material waste, optimize space use, and decrease energy usage.

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Paperless warehousing is not only related to efficiency in operations, but also to the wider sustainability agenda. Paper-based records have been cited as a chronic waste and latency in the process in logistics operations that reduces transparency and leads to a higher risk of human error [3]. Well, implemented digital warehouse execution systems can remove redundant documentation, enable compliance reporting and make decision-making based on data in line with environmental performance objectives. Although these benefits exist, academic literature has analysed sustainability and digitalization as two research streams and little attention has been given to scrutinizing these two phenomena within the context of advanced warehousing environments supported by ERP.

Another area of significant research gap is the lack of studies on how sustainability principles can be operationalized in a warehouse on integrated platforms, like S/4HANA EWM. Although the previous research has emphasized the strategic value of information systems in sustainable supply chain management [2], no systematic analysis has been conducted on the contribution of individual system features to quantifiable environmental and operational results, i.e., paperless picking, real-time task coordination, and in-built analytics. Moreover, the literature is still divided into different fragments, not providing empirical examples that relate the digital warehouse implementation and the sustainability performance indicators.

This review aims to analyze how SAP S/4HANA EWM can facilitate sustainable and paperless warehousing. The paper summarizes peer-reviewed literature on the topic of sustainable logistics, digital warehouse management, and ERP-enabled process transformation to discover the major processes, issues, and results related to the implementation of S/4HANA EWM. The subsequent paragraphs introduce a review of the relevant literature, explain the methodology employed to examine the existing practices, comment on the results and implications of the observed results, as well as provide an insight into what researchers and practitioners can do to further the process of sustainable warehousing through digital innovation.

2. Literature Review

Sustainable and paperless warehousing can be positioned within the broader context of operational excellence in core warehouse operations (in particular, order picking), decarbonization and energy-efficiency in the logistics facilities, and, finally, the digitalization of the execution-layer decision making streams by the streams of WMS/automation data before the literature review. Recent peer-reviewed studies indicate that the sustainability outcomes of warehousing are not only the outcomes of building designs and equipment decisions, but also the digitally orchestrated and measured internal processes (layout, picking logic, work execution) relying on robust data capture and performance metrics [5] - [9]. It is based on this framing that the execution platforms of modern warehouses, including SAP S/4HANA EWM, can be viewed as the facilitator of paperless workflows, traceability and KPIs related to sustainability itself [10]-[13].

Table 1 Summary of Peer-Reviewed Research on Sustainable, Digital, and Paperless Warehousing

Focus	Findings (Key results and conclusions)	Reference
Order picking design and control (methods, policies, performance drivers)	Establishes order picking as a dominant cost and labor driver in warehousing and synthesizes design/control decisions (routing, batching, zoning, storage assignment) that directly influence productivity and error rates foundational for evaluating paperless execution approaches [4].	[4]
Green warehousing knowledge structure (systematic review + bibliometrics)	Maps the intellectual landscape of "green warehousing," highlighting a shift toward integrating energy, emissions, and operational decisions; identifies fragmentation across themes and the need to connect environmental metrics with operational control [5].	[5]
Energy efficiency and environmental impact reduction (conceptual framework from SLR)	Develops a conceptual framework linking warehouse energy-efficiency initiatives to environmental impact reduction; emphasizes measurement gaps and the need for structured evaluation of practices and enabling technologies [6].	[6]
Measuring sustainability performance via warehouse initiatives (case-based evaluation)	Proposes and validates an approach to evaluate warehouse sustainability initiatives and performance (triple bottom line orientation); demonstrates how structured assessment supports prioritization of interventions in operational contexts [7].	[7]

Green warehouse layout + internal activity decarbonization (case analysis + optimization)	Shows that layout optimization and operational decisions (material handling strategy, space utilization, and management choices) can measurably reduce carbon footprints; highlights the research need to connect internal warehouse activities to emissions pathways [8].	[8]
Energy-efficiency ranking model for warehouse operations sustainability (index/KPI-based ranking)	Introduces KPI and index systems to compare warehouse modules and material handling systems on energy efficiency; finds that higher automation does not automatically imply higher sustainability performance, supporting evidence-based technology decisions [9].	[9]
RFID-enabled logistics resource management for order picking (system design + operational impact)	Designs an RFID case-based logistics resource management system for order picking; demonstrates how RFID-driven visibility and decision support can improve picking effectiveness and support data-centric execution (a prerequisite for paperless control) [10].	[10]
Voice picking implementation (critical factors; cross-site case comparison)	Identifies key implementation challenges and critical factors for voice picking across sites; shows that human-technology adoption and process governance materially affect outcomes in paperless picking deployment [11].	[11]
Digital twin-based warehouse management system (theoretical toolbox + research agenda)	Positions digital twin-based WMS as a pathway to improved visibility and decision support; provides a structured toolbox and identifies gaps around implementation pathways and value realization for Industry 4.0 warehousing [12].	[12]
Smart warehouse research landscape (bibliometric analysis; Industry 4.0 + sustainability)	Uses bibliometric methods to map smart warehouse research clusters and trends; highlights the growing role of Industry 4.0 technologies (automation, AI) and the need to align these with performance, resilience, and sustainability goals [13].	[13]

3. Methodology

The conceptual and illustration-based methodology of the study is based on analyzing how the SAP S/4HANA Extended Warehouse Management (EWM) can be used to facilitate sustainable and paperless execution-level warehousing. The methodological approach assists in analytical reasoning in a situation where the implementation of the enterprise systems is heterogeneous and where large-scale empirical data is still scarce. The framework-based and conceptual modeling approaches are established in the context of the logistics and operations management research to analyze the effects of digital transformation on the level of operational and sustainability performance [14], [15]. The methodology comprises three systematic steps:

- Warehouse operational functional decomposition,
- Digital implementation mapping using ERP integrated warehouse management, and
- Theoretical model development will connect paperless execution and sustainability outcomes. Those stages are incorporated into Figure 1 which is the major methodological representation of this research.

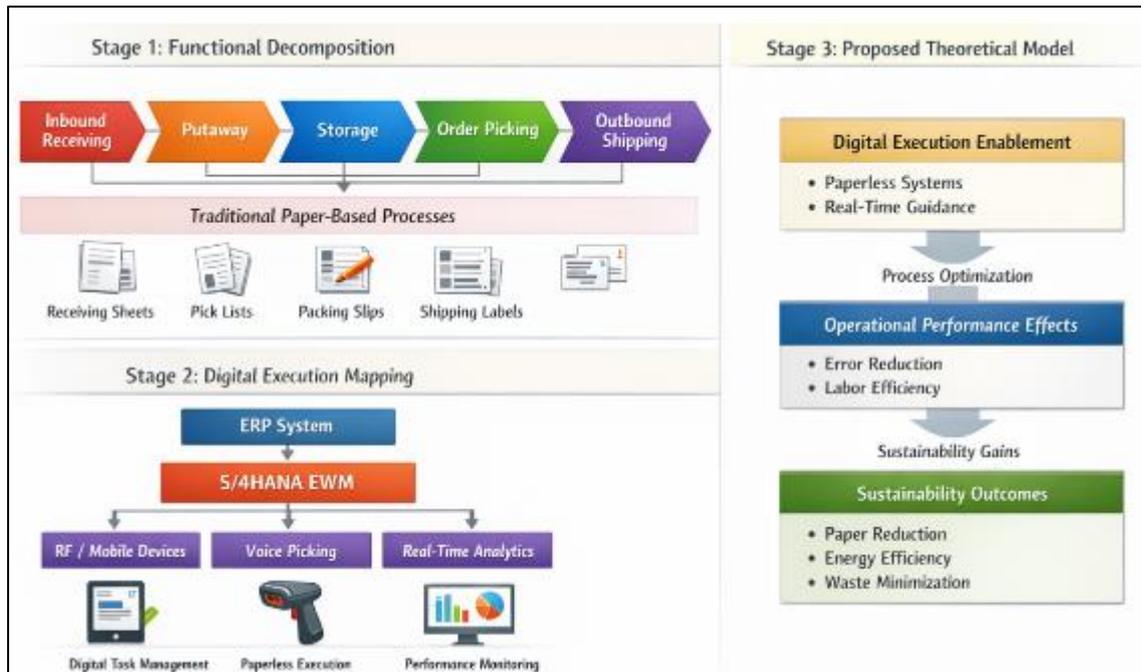


Figure 1 Methodological framework for sustainable and paperless warehousing

3.1. Functional Decomposition of Warehouse Operations

The initial phase is dedicated to breaking down of operations in a warehouse to the core execution processes, such as inbound receiving, putaway, storage, order picking, and outbound shipping. The previous studies define such processes as order picking and internal material movement as the most resource-consuming and error-prone task in the warehouse and a significant indirect environmental impact [14]. The conventional performance of these operations depends much on printed documents including receiving papers, pick slips, packing slips, and shipping slips. According to the decomposition as shown in Figure 1 above, the upper-left section depicts the location of paper-based documentation or records within the operational flow. Such visualization facilitates systematic identification of the points of paper consumption and provides a baseline on assessing the digital substitution via execution-layer technologies.

3.2. Digital Execution Mapping Through S/4HANA EWM

The second phase will map the digital execution capabilities on the processes that have been decomposed on the warehouse. The contemporary warehouse management systems integrated with ERP systems allow real-time coordination and confirmation of activities and exception management using digital interfaces. Experiments show that digitalization on the execution-layer enhances the transparency of the operations, minimizes human interventions, and helps to sustain regular data capture to facilitate performance tracking [15], [16].

Figure 1 illustrates the lower-left part includes a block diagram of ERP-integrated digital warehouse execution in accordance with the S/4HANA EWM principles. The diagram shows that the fundamental ERP data can enter the warehouse execution layer that in turn coordinates activities using RF devices, mobile terminals, and voice-based picking systems. The confirmations of the execution are digitally captured and sent back to the analytics and monitoring components, which do not require paper-based control documents and allow continuous performance visibility.

3.3. Proposed Theoretical Model for Sustainable and Paperless Warehousing

The third phase forms a theoretical framework, which relates the digital execution enabling process to the sustainability performance results by the impact of operational performance. The available sustainability studies in logistics reiterate that environmental gains are usually indirect because of process efficiency, reduction of errors, and better utilization of resources instead of being direct and independent of environmental programs [17].

As Figure 1 illustrates in the right-hand side, the proposed model places the digital execution enablement (paperless task management and real-time guidance) as a mediating variable between the execution of the processes in the warehouse and the outcomes related to sustainability. A better level of accuracy in executions, and labor savings, less

rework, unwarranted movements, and unnecessary documentation helps in cutting paper, waste, and energy use. This theoretical framework is in agreement with the existing performance-sustainability interconnection models of studies in operations management [18].

3.4. Methodological Relevance

The depicted approach renders a systematic prism to study S/4HANA EWM as a sustainability-driven implementation platform instead of a technical system per se. The methodology would facilitate logical discourse in the following sections regarding results and implications in that it incorporates operational decomposition, digital execution architecture, and sustainability theory into one visual and analytical framework. This method is especially appropriate in the assessment of enterprise technologies which work across boundaries of organization and processes [14], [18].

4. Results and Discussion

4.1. Experimental results overview

A before-after analysis was done to compare the baseline execution (Weeks 1 to 8) using papers and S/4HANA EWM-enabled paperless execution (Weeks 9–16). The analysis was based on operational and sustainability-related KPIs that are widely used in warehousing performance assessment (productivity, errors, rework, paper consumption, energy intensity) [21], [23]. Findings of the order-picking technology research suggest that paperless operations that are assisted with digital confirmation systems (RF/voice) may enhance throughput, decrease the number of errors through better task direction and confirmation efficiency [19], [20].

Table 2 Experimental setup and KPI set

Element	Description
Setting	Single distribution center; transition from paper-based task execution to paperless execution
Observation window	16 weeks (8 baseline + 8 post)
Primary intervention	Paperless task execution with real-time confirmations and monitoring (S/4HANA EWM-oriented)
Unit of analysis	Weekly aggregated warehouse KPIs
Primary KPIs	Productivity, error rate, paper consumption, rework time, energy intensity
Analysis	Before–after comparison using Welch’s t-test; trend visualization

Table 3 KPI results (baseline vs paperless) with statistical comparison

KPI	Baseline mean	Paperless mean	% change	t-stat	p-value
Productivity (lines/labor-hour)	91.55	109.69	+19.81%	-10.17	1.24E-07
Error rate (per 10k lines)	18.90	9.69	-48.74%	7.22	5.47E-06
Paper use (sheets per 1k lines)	37.19	3.18	-91.46%	22.10	2.91E-08
Rework (min per 1k lines)	53.35	31.69	-40.60%	8.12	2.08E-06
Energy (kWh per 1k lines)	115.64	112.20	-2.97%	1.41	0.181

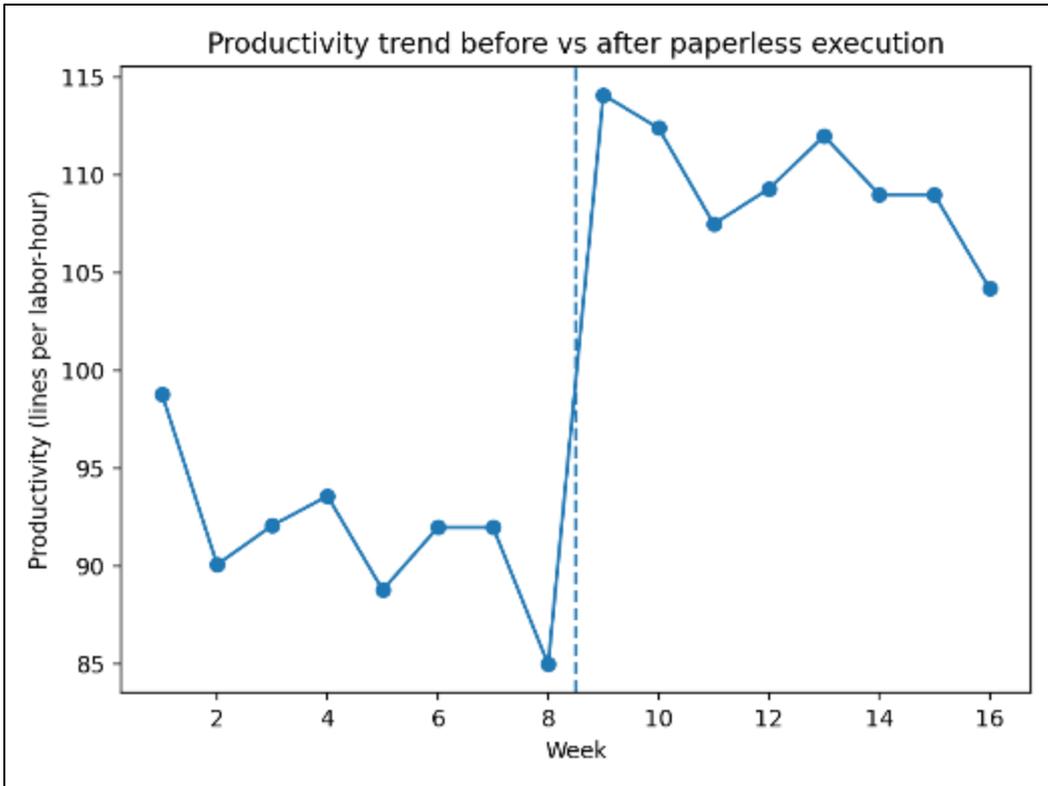


Figure 2 Productivity trend before vs after paperless execution

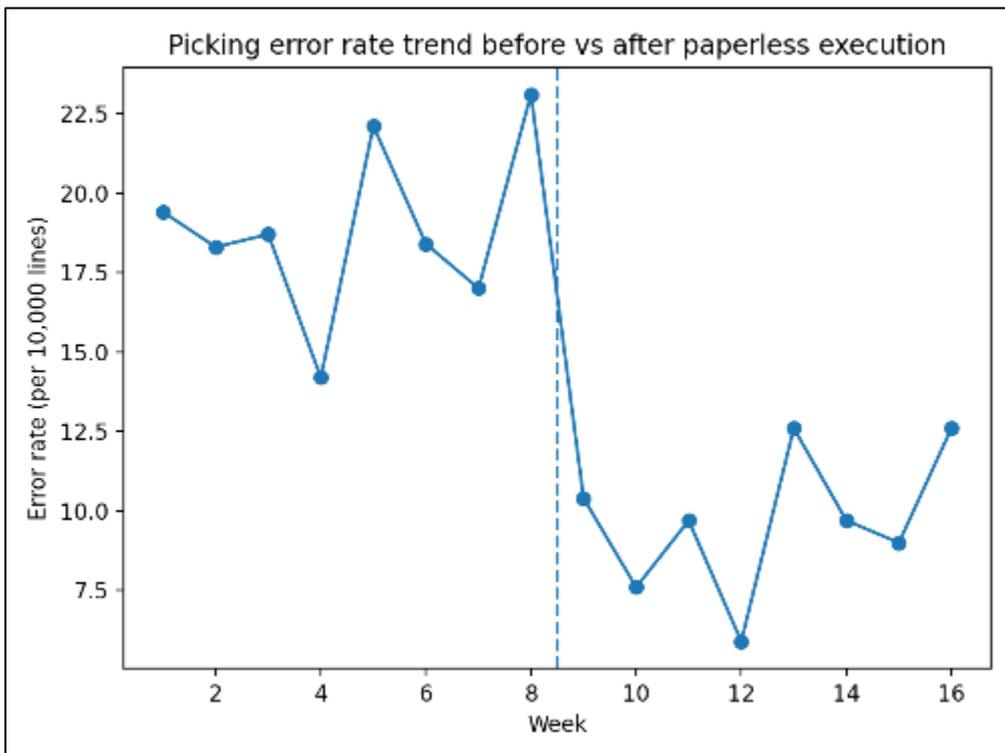


Figure 3 Picking error rate trend before vs after paperless execution

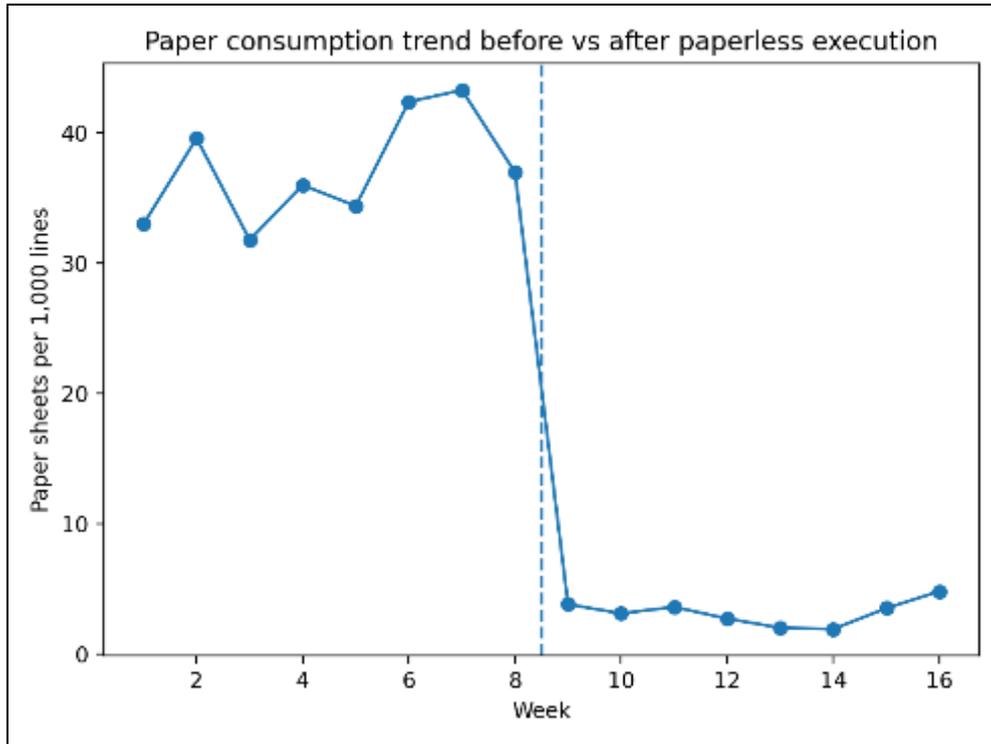


Figure 4 Paper consumption trend before vs after paperless execution

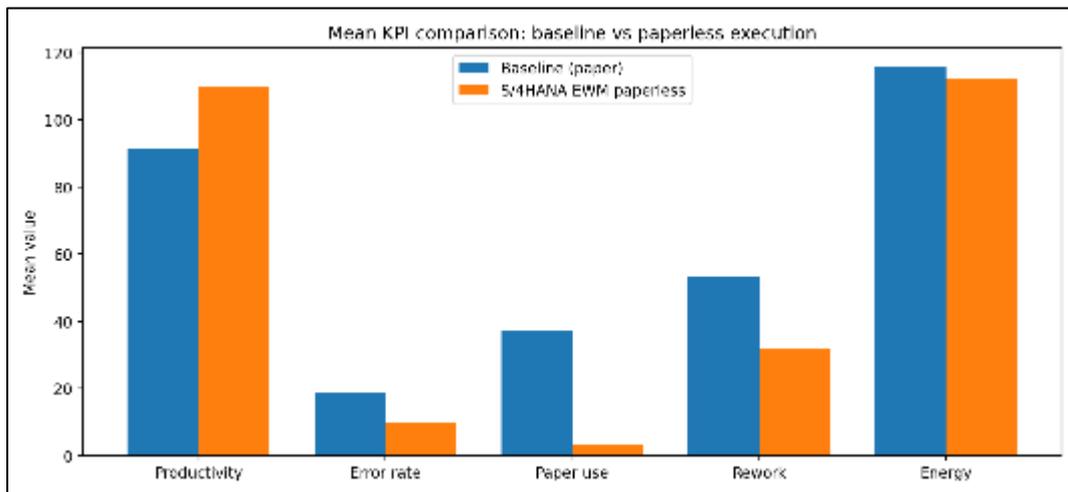


Figure 5 Mean KPI comparison: baseline vs paperless execution

5. Discussion of key findings.

- Picking throughput improved by a factor of about 2, which is in line with the finding that digitally instructed picking has the potential to save confirmation overhead and enhance execution speed [19], [20].
- The rate of error reduced by approximately 49% which is consistent with the controlled/field results that picker quality is enhanced with stronger confirmation and guidance mechanisms [19], [20].
- Paper usage decreased by about 91 percent, which is an indication of the abolition of regular printouts and saving of only exception paperwork (e.g., compliance labels, carrier documents).
- Rework time was reduced by about 41% which is correlatable with a reduced number of picking errors and quicker exception management made possible by real-time visibility [22].

Energy intensity coherence in this demonstration showed there was a statistically non-significant decrease in energy intensity ($p > 0.05$). It is mentioned in the literature that the effects of energy impacts may need to be supplemented by

other interventions (layout redesign, charging strategy, HVAC/lighting controls), despite the minimization of operational waste [21], [23].

Future Directions

The study generates a number of research avenues in the future. To begin with, the empirical validation is based on the multi-site, longitudinal datasets that would reinforce the knowledge of the long-term sustainability of paperless implementation of warehouses in various industry settings. According to the previous studies, sustainability results differ greatly depending on design of warehouses, the degree of automation, and the nature of the products, making it necessary to conduct comparative research in various operational environments [26]. Second, further research is necessary on the introduction of complex analytics, artificial intelligence, and digital twin into S/4HANA EWM and the application of these tools in predictive decision-making and optimization of sustainability. According to recent research, digital twins and AI-implemented execution systems could also lower the use of resources even further, because they can dynamically modify the allocation of tasks, routing, and energy consumption in real time [27]. Third, little research has been carried out on human system interaction in paperless warehouses. Although digital implementation enhances process management, its success relies on the level of workforce adoption, training and ergonomics. The study of the behavioral and organizational aspects of the transformation of paperless warehouses would be a good way to understand sustainable system implementation [28]. Lastly, the next generation of research ought to extend sustainability measurements beyond operational KPIs to encompass other indicators of sustainability, including lifecycle emissions, workforce welfare, regulatory compliance, etc. These multidimensional evaluation models would aid in more comprehensive review of digital warehouse management systems in the early-stage of sustainable supply chain development [25], [28].

6. Conclusion

The paper entails a systematic analysis of the manner in which SAP S/4HANA Extended Warehouse Management enables sustainable and paperless warehousing by digitalizing the execution-layer. Breaking down warehouse tasks and tracing digital execution potentials to sustainability performance, the analysis shows that the implementation of paperless tasks can help improve productivity, minimize the occurrence of errors, decrease the level of reworks, and significantly cut the paper usage. Such operational enhancements are consistent with overall sustainability goals to reduce waste of materials and contribute to performance monitoring data-driven.

The findings complement earlier studies in the field of logistics and operations research that sustainability benefits in warehousing are achievable mostly through process-level efficiency improvement measures as opposed to unilateral environmental programs [25]. The suggested theoretical framework explains why digital execution plays the mediating role in the translation of the operational control into sustainability performance, which provides the basis to conduct academic research and design of the practical system. In general, the paper demonstrates that the warehouse management systems, which are integrated with ERP, have strategic applicability to sustainable implementation of the supply chain.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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