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Adoption of Automated Sorting Technologies in Retail Supply Chains: A Comparative Study of Landmark Group (UAE) and DAL Group (Sudan)

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Abstract: Automated sorting has become one of the principal mechanisms by which warehouses evolve from static storage facilities into responsive service hubs. This paper examines how the adoption of automated sorting technology shapes operating performance in start-up and emerging-market business settings, comparing an advanced adopter with an early adopter operating under significant infrastructural constraints. Using an exploratory qualitative design, the study draws on semi-structured interviews with supply chain managers at Landmark Group (United Arab Emirates) and DAL Group (Sudan). Transcripts were examined through content analysis organized around four themes: production speed, economic and service benefits, technical and implementation challenges, and maintenance response. Both firms reported that automated sorting shortened cycle times, reduced manual intervention, and improved dispatch accuracy, and both linked these gains to lower operating costs and more reliable delivery performance. The Sudanese case reported an increase of approximately 43% in production capacity and roughly 50% in sorting speed, though it also identified unstable electricity supply, scarcity of spare parts, a shortage of skilled technicians, and organizational resistance to change as binding constraints on sustained performance. By contrast, the Landmark case reported a transition from reactive repair toward predictive maintenance and the emergence of new technical occupations rather than straightforward labor displacement. The study concludes that the performance gap between the two settings is driven less by the sorting technology itself than by the supporting infrastructure, maintenance capability, and change-management capacity surrounding it, and it offers recommendations for start-ups, policymakers, and future research.

Keywords: *Automated Sorting Systems; Warehouse Performance; Supply Chain Management; Start-Up Business; Logistics Automation; UAE; Sudan.*

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I. INTRODUCTION

In the contemporary global retail landscape, the pursuit of operational excellence has shifted from a secondary strategic objective to a fundamental precondition for supply chain survival (Boysen et al., 2019). Firms are increasingly replacing labor-intensive models with advanced technological interventions in order to contain rising operational costs and meet escalating consumer expectations for speed and accuracy (Acemoglu & Restrepo, 2018b; Brynjolfsson & McAfee, 2014). This restructuring of work is well documented in the automation literature, which shows that technological adoption not only reduces reliance on manual labor but also reshapes the skill composition of the workforce (Frey & Osborne, 2017; Graetz & Michaels, 2018). Central to this transformation is the adoption of automated sorting systems (ASS) (Hamzah & Abbas, 2020). These systems function as critical intralogistics nodes, identifying, routing, and sequencing materials within distribution centers so as to convert unpredictable inbound flows into synchronized outbound consignments (Dematic, 2020; Tanguay-Rioux et al., 2022). By integrating sensing, actuation, and sophisticated software control, ASS minimizes manual handling and redefines the warehouse as a high-velocity fulfillment node rather than a static storage facility (Sundarakani, 2017; de Koster et al., 2007).

➢ *Problem Statement*

Despite the global proliferation of automation, emerging markets such as Sudan continue to face substantial structural barriers to adoption. Within the Sudanese retail sector, the implementation of automated sorting is hindered by the absence of empirical frameworks capable of evaluating system sustainability and long-term viability. As supply chain requirements evolve, existing facilities often undergo fragmented reconfigurations that fail to keep pace with demand. As a result, many sorting installations in the region remain technologically outdated, producing systemic inefficiencies, inflated operating expenditures, and heightened occupational safety risks (Lawal & Isiyaku, 2025). There remains a critical lack of a standardized basis on which firms can weigh the high capital investment required by automation against its subsequent operational and environmental returns.

➢ *Research Gap*

The existing literature on warehouse automation remains heavily weighted toward high-income economies, with research in developing contexts tending to focus on macro-level trade effects rather than facility-level operational dynamics. Few studies have examined the distinct socio-technical challenges of absorbing advanced sorting technologies in environments characterized by fragile power infrastructure, thin supplier networks, and a scarcity of specialized technical labor (Mann, 2013). This study addresses that theoretical and empirical gap by offering a comparative analysis of an established regional leader (Landmark Group, UAE) and an early-stage adopter (DAL Group, Sudan), identifying the boundary conditions that facilitate or impede successful technology transfer.

➢ *Research Objectives*

The primary objectives of this study are to:

- Evaluate the impact of automated sorting implementation on organizational production speed and throughput efficiency.
- Analyze the economic returns and customer service improvements derived from automated sorting investments.
- Categorize the technical and systemic implementation challenges unique to emerging-market contexts.
- Examine the strategic maintenance and breakdown-recovery protocols firms adopt to ensure system resilience.

➢ *Research Questions*

To achieve these objectives, the study addresses the following questions:

- How does the implementation of automated sorting influence the operational throughput and production velocity of the firm?
- What specific economic benefits and customer-centric performance metrics are enhanced by the use of these technologies?
- What are the prevailing technical and structural barriers to the successful implementation of automated sorting systems?
- How do firms navigate maintenance requirements and mitigate the risks of system downtime in volatile operating environments?

➢ *Significance of the Study*

This research contributes to both theory and practice across four dimensions. Economically, optimized warehouse operations support lower distribution costs and, by extension, regional economic integration. Operationally, the findings offer Sudanese firms a realistic roadmap for adoption that highlights common failure points. From a policy standpoint, the evidence underscores the need for public investment in reliable energy provision and technical vocational training. Finally, from a technology-transfer perspective, the comparison clarifies the readiness criteria essential for importing sophisticated logistics solutions into markedly different operating environments.

II. LITERATURE REVIEW

➢ *Automated Sorting: Technology and Decision Logic*

Automated sorting has moved from a specialized operational tool to a ubiquitous component of modern intralogistics, driven by the twin imperatives of reducing cycle times and maximizing throughput. In contemporary supply chain configurations, the decision logic of these systems typically involves a sensor–microcontroller interface in which routing is determined by physical or informational attributes such as color, shape, volume, or SKU type. Actuation mechanisms—ranging from robotic arms to pneumatic diverters—are increasingly governed by machine vision and artificial intelligence rather than by rudimentary single-variable sensing.

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Hamzah and Abbas (2020) illustrate this technological trajectory through their development of vision-based systems that employ real-time template matching. Their research shows that converting captured images into binary data for edge detection enables the sorting of complex geometries at varying orientations. The effectiveness of such systems, however, is constrained by optical variables such as illumination intensity and source-to-conveyor distance. For firms operating in developing economies, these technical requirements represent significant operational barriers, given that ambient environmental conditions are often less controlled than in high-income logistics hubs.

➢ *Sorting Facilities in the Logistics Network*

The growth of e-commerce has fundamentally restructured distribution networks into a multi-layered hierarchy of specialized facilities (Boysen et al., 2019). Rodrigue (2020) conceptualizes the modern logistics corridor as a sequence of nodes—including inbound cross-dock facilities, e-fulfillment centers, and sortation hubs—each playing a distinct role in the movement of goods. Sortation centers, in particular, serve as critical velocity points at which parcels are disaggregated by final destination.

From a strategic perspective, the implementation of sorting technology is not an isolated capital investment but a systemic one. Its return on investment depends heavily on the synchronization of upstream fulfillment and downstream last-mile delivery. As the literature notes, automating a sorting node without corresponding capacity in adjacent nodes tends merely to relocate the operational bottleneck rather than resolve it.

➢ *Order Picking, Storage, and the Case for Automation*

Within the warehouse environment, order picking represents the most labor-intensive and cost-prohibitive activity. De Koster et al. (2007) estimate that picking operations account for up to 55% of total warehouse operating expenses, providing a strong economic rationale for automation. Modern installations draw on a range of technologies, from Automated Storage and Retrieval Systems (AS/RS) that optimize storage density to Autonomous Mobile Robots (AMRs) that support product-to-picker workflows.

The integration of Radio-Frequency Identification (RFID) has further enhanced traceability beyond the limits of traditional optical scanning. Unlike barcodes, RFID tags do not require a direct line of sight and allow multiple items to be processed simultaneously, reducing both manual handling and error rates in high-volume environments.

➢ *Automation, Labor, and Developing Economies*

The economic discourse on automation is heavily shaped by the task-based approach, which distinguishes routine tasks susceptible to substitution from non-routine tasks requiring human cognitive flexibility (Autor et al., 2003). While early estimates by Frey and Osborne (2017) suggested high levels of occupational displacement, subsequent analyses by Arntz et al. (2016) argue that task heterogeneity within jobs mitigates the overall risk to the labor market.

For developing economies such as Sudan, the implications of automation are often transmitted through trade channels. Acemoglu and Restrepo (2018) and Artuç et al. (2018) show that robot adoption in advanced economies can encourage the reshoring of manufacturing, potentially marginalizing developing nations that rely on labor-cost advantages. Consequently, the adoption of sorting technologies in Sudan is not merely a matter of domestic efficiency but a strategic necessity for maintaining relevance within global trade networks (World Bank, 2019).

III. METHODOLOGY

➢ *Research Design*

This study employs an exploratory, qualitative research design. Given the still-emerging state of warehouse automation research within the Sudanese context, a qualitative approach is necessary to capture the operational realities and socio-technical constraints that quantitative metrics alone might overlook. The research is structured as a comparative case study, allowing for an in-depth investigation of how automated sorting systems are absorbed into distinct institutional environments. This design supports the identification of operative constraints and the development of a localized theoretical framework, rather than the testing of pre-specified hypotheses (Eisenhardt, 1989).

➢ *Research Setting and Context*

The study adopts an asymmetric comparative framework, focusing on two organizations that represent different stages of the technology-adoption curve:

- Landmark Group (UAE): Headquartered in Dubai, this organization represents the mature-adopter benchmark. Operating within a high-income, high-infrastructure environment, its Mega Distribution Centre in Jebel Ali serves as a global exemplar of logistics automation.
- DAL Group (Sudan): Representing the emerging adopter, this Sudanese conglomerate operates within a complex environment characterized by infrastructure deficits and economic volatility.

This comparison serves to isolate the environmental and institutional variables that determine the success of technology transfer in retail supply chains.

➢ *Sampling Strategy and Informants*

To ensure high data validity, the study employed a purposive sampling strategy to recruit expert informants with direct oversight of sorting operations. The sample comprised ten senior managers (N = 10), divided equally between the two organizations (n = 5 per case). Informants were selected on the basis of three criteria: (1) a minimum of five years of experience in supply chain management, (2) direct involvement in the procurement or implementation of sorting technologies, and (3)

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responsibility for warehouse performance metrics. This small-scale, matched-pair approach prioritizes depth of insight over statistical generalizability, consistent with exploratory case research (Yin, 2017).

➢ *Data Collection and Sources*

Primary data were gathered through semi-structured interviews, which provided the flexibility to probe emergent themes while maintaining a consistent thematic focus. The interview protocol consisted of fifteen core items organized into six dimensions:

- Technical integration: equipment specifications and software interoperability.
- Operational performance: impact on throughput speed and error rates.
- Economic viability: cost–benefit ratios and customer service improvements.
- Human capital: employment effects and technical training requirements.
- Resilience: maintenance strategies and breakdown management.
- Institutional factors: regulatory and infrastructure challenges.

Interviews were supplemented by secondary data sources, including internal corporate reports, technical documentation of the Dematic and SAP systems used by the firms, and existing scholarly literature on regional logistics trends. This triangulation of data sources strengthens the reliability of the findings.

➢ *Data Analysis*

The qualitative data derived from the semi-structured interviews were processed using a systematic content-analysis framework designed to identify, analyze, and report patterns within the data (Krippendorff, 2018). The analysis followed a multi-stage coding procedure: initial open coding was used to categorize the raw data, followed by axial coding to organize these categories into higher-order themes aligned with the study's core objectives—namely, operational velocity, economic viability, implementation barriers, and maintenance resilience. To strengthen the robustness of the findings, a cross-case comparative analysis was conducted to highlight the divergence in adoption trajectories between the mature institutional environment of the UAE and the more volatile market context of Sudan. Quantitative performance metrics provided by participants were treated as perceptual data reflecting managerial assessments of operational impact, offering insight into how the technology's utility is perceived rather than serving as audited performance figures.

➢ *Scope and Limitations*

This study is bounded by its specific focus on the adoption of automated sorting technologies within the retail distribution sectors of the UAE and Sudan during the 2024–2025 period. Several limitations inherent to the exploratory qualitative design should be noted. First, the purposive sample of ten managers offers considerable contextual depth but does not support statistical generalization to the broader population of logistics firms; the study prioritizes analytical generalizability to theory over statistical generalizability to a population (Yin, 2018). Second, reliance on self-reported operational data introduces the possibility of response bias; while these insights remain valuable for understanding managerial decision-making, they were not verified against audited longitudinal records. Finally, the pronounced differences in national infrastructure and market maturity between the two regions are treated as contextual variables that shape technology absorption rather than as controlled factors. These boundaries provide a foundation for future quantitative research to test the identified constraints across a wider geographic and industrial scope.

IV. RESULTS

This section presents the empirical findings from the comparative analysis of Landmark Group and the Sudanese focal firm. The discussion situates these results within the broader theoretical framework of supply chain sustainability, examining the interplay between economic viability, environmental stewardship, and operational efficiency.

➢ *Organizational Context and Maturity*

Landmark Group, established in 1973, is a mature, diversified retail and hospitality conglomerate. With a footprint exceeding 2,200 outlets across the GCC, Africa, and Southeast Asia, the group has successfully transitioned into a sophisticated omnichannel operator (Dematic, 2020). The Sudanese focal firm, by contrast, represents an emerging adopter operating within a more volatile market. This disparity in organizational maturity offers a useful matched-pair perspective, allowing environmental constraints to be isolated from firm-specific capabilities.

➢ *Operational Velocity and Throughput Efficiency*

Evidence from both firms points to a positive relationship between automated sorting and operational velocity. The Landmark respondent noted that the Omega Mega Distribution Centre in JAFZA has become a logistics benchmark for the region, significantly reducing lead times and improving inventory turnover (Sundarakani, 2017).

Quantitatively, the Sudanese respondent reported a 43% increase in total production capacity and a 50% improvement in sorting speed following the adoption of the technology. Consistent with recent literature on emerging economies, the marginal benefit of automation appears most pronounced in environments transitioning away from highly manual legacy processes (Lawal & Isiyaku, 2025).

➢ *Business Process Optimization and Reliability*

The findings suggest that automated sorting acts as a catalyst for broader process improvement. Both respondents identified the elimination of manual touchpoints as the primary

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driver of increased accuracy and reduced cycle times. The Sudanese respondent emphasized that system-driven data capture—covering product attributes and quality metrics—helps ensure a standardized customer experience. This is consistent with a traceability advantage, in which the value proposition of automation shifts from handling speed alone toward the integrity of real-time supply chain data.

➢ *Economic and Environmental Sustainability*

A notable divergence emerged in how sustainability is pursued. Landmark Group has embedded environmental goals within its core logistics strategy; the Omega facility is solar-powered, generating a triple-bottom-line benefit in which energy efficiency lowers operating costs while also reducing the carbon footprint (Dematic, 2020).

Within the Sudanese context, economic sustainability is viewed primarily through the lens of loss prevention and headcount optimization. Where Landmark emphasizes green logistics, the Sudanese firm prioritizes what might be termed survivalist efficiency—using the technology to redistribute roles and reduce the costs associated with human error in a high-inflation environment.

➢ *Technological Synergies: AI, IoT, and Big Data*

Landmark Group reported a more advanced technological trajectory, incorporating artificial intelligence and the Internet of Things for predictive demand forecasting and pattern optimization. The Sudanese firm, by contrast, remains at the data-acquisition stage, focused on establishing the foundational accuracy of its Warehouse Management System. This pattern confirms that technological adoption in retail supply chains is a path-dependent process, in which advanced analytics require a robust, automated physical layer before they can be effective.

➢ *Strategic Outcomes: Profitability and Human Capital*

Both firms reported enhanced customer loyalty resulting from faster fulfillment and reduced return rates. The impact on human capital, however, differed considerably. Landmark Group described a labor transformation in which routine manual tasks were replaced by specialized roles in system analysis and robotics maintenance (Dematic, 2020).

The Sudanese respondent, by contrast, framed the impact primarily as a reduction in total labor requirements. This is consistent with the findings of Arntz et al. (2016), which suggest that in markets with a shallow technical labor pool, automation tends to be perceived as a direct substitute for labor rather than as a tool for upskilling.

➢ *Implementation Barriers and Contextual Constraints*

An asymmetry of constraints emerged as a central theme across the two cases. Landmark Group's challenges were primarily internal—high capital expenditure and system compatibility—characteristic of frontier adopters operating within stable economies.

The Sudanese firm, however, faces external systemic barriers:

- Infrastructure: inconsistent power supply remains the primary inhibitor of consistent performance.
- Supply chain thinness: a critical shortage of spare parts and specialized technical support.
- Cultural resistance: significant organizational pushback against automated workflows.

These findings suggest that in emerging markets, institutional voids may substantially erode the theoretical efficiencies promised by high-end sorting technologies.

➢ *Asset Lifecycle and Maintenance Strategies*

A further point of divergence concerns maintenance paradigms. Landmark Group employs predictive maintenance protocols and around-the-clock remote support to keep downtime close to zero (Dematic, 2020). The Sudanese firm, by contrast, relies on a reactive maintenance model, constrained by the limited availability of local expertise and parts. Because the return on investment from automated sorting depends on sustained high utilization rates, the absence of proactive maintenance infrastructure in Sudan represents a meaningful risk to the long-term sustainability of such investments.

➢ *Comparative Summary*

Table 1. Comparative summary of interview findings.

Dimension	Landmark Group (UAE)	Sudanese Company
Effect on speed	Marked gain in throughput; faster order turnaround at the Omega DC	Capacity up ~43%; sorting speed up ~50%
Process role	Fewer manual touches; higher dispatch accuracy	Fewer manual touches; data-fed systems reduce error
Cost effect	Lower labour cost per unit; solar-powered DC lowers energy cost	Large cost reduction; losses down, quality up

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Dimension	Landmark Group (UAE)	Sudanese Company
Employment	New roles in system analysis, controls, and robotics maintenance	Headcount reduced; roles rotated and redefined
Technology plans	AI, big data, and IoT under evaluation	Data capture for product quality and customer experience
Main constraints	High capital outlay; skilled installation; legacy-system compatibility	Power supply, resistance to change, spare parts, skills shortage
Maintenance	Predictive maintenance and scheduled checks by trained technicians	Reactive; constrained by spare-part availability

V. DISCUSSION

Taken together, the comparative data from Landmark Group and the Sudanese firm point to a critical observation: the technical performance of automated sorting hardware is not, on its own, the primary determinant of supply chain success. Rather, the operational utility of these systems depends on the robustness of the enabling infrastructure surrounding the installation. While both organizations achieved significant gains in throughput—with the Sudanese firm reporting a disproportionately high 43% increase in capacity—the sustainability of these gains is contingent on external variables that lie largely outside the firm's direct control.

The findings also reveal a structural divergence in adoption constraints. For the advanced adopter, Landmark, challenges are primarily financial and front-loaded, centered on capital expenditure and initial system integration. For the emerging-market firm, by contrast, the barriers are persistent and systemic: unreliable power infrastructure, fragmented spare-part supply chains, a shallow technical labor pool, and organizational resistance to digital transformation. This pattern suggests that in developing contexts, the cumulative cost of maintaining system uptime amid infrastructure deficits—what might be termed the cost of availability—can outweigh the initial acquisition cost over the asset's lifecycle.

These findings also lend empirical weight to the trade-channel theories advanced by Micco (2019) and Artuç et al. (2018). As advanced economies automate their fulfillment networks, firms in emerging markets such as Sudan face a dual pressure: they must adopt labor-displacing technologies in order to remain competitive within global trade relationships, yet must do so within an operating environment that substantially raises the risk of system failure. Successful adoption in these contexts therefore appears to require a shift away from a purely capital-expenditure-focused investment model toward one that prioritizes resilient maintenance regimes and localized technical training.

VI. CONCLUSION AND RECOMMENDATIONS

➢ *Conclusion*

This study demonstrates that the adoption of automated sorting technologies is a primary driver of operational excellence in retail supply chains, regardless of organizational scale or regional context. The comparative analysis of Landmark Group and the Sudanese case shows that while the underlying mechanisms of sorting technology—sensor-based divert systems and vision-based classification, among others—are broadly standardized, their successful implementation depends heavily on environmental and infrastructural conditions.

Both organizations achieved meaningful improvements in cycle times, accuracy, and process reliability, directly supporting supply chain resilience. The Sudanese experience, however, highlights a critical implementation gap in which the gains from automation are frequently offset by external constraints such as energy instability and thin maintenance networks. The central conclusion of this research, therefore, is that the sustainability of automated sorting depends less on the technical specifications of the equipment itself and more on the robustness of the supporting ecosystem—power continuity, technical human capital, and proactive maintenance regimes.

➢ *Recommendations*

Based on these findings, the following strategic recommendations are proposed for firms and policymakers operating in emerging markets:

- Establish predictive maintenance protocols. Firms should shift from reactive to proactive maintenance, with specialized on-site technicians appointed to identify latent technical faults before they escalate into system-wide failures.
- Integrate power and infrastructure planning. In environments with unreliable grids, investment in sorting technology should be paired with investment in redundant power systems, such as solar integration or UPS arrays, with power continuity treated as a core component of the technology's lifecycle cost rather than an external variable.

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- Manage spare-part inventory strategically. Given localized shortages of technical components, firms should maintain a critical-parts inventory based on realistic lead times and failure-rate data to limit prolonged operational downtime.
- Invest in capacity building and specialized training. Public and private sector stakeholders should collaborate to deliver technical workshops focused on automation management, mitigating the shallow-labor-market constraint and reducing organizational resistance to change through workforce upskilling.
- Adopt scalable automation strategies. Start-up businesses should favor modular automation systems that allow for incremental scaling as technical proficiency and local infrastructure improve.
- Pursue further research. Future studies should expand the sample size to support cross-sectoral generalizations and draw on longitudinal operational data to verify self-reported performance metrics. Research into the integration of AI-driven predictive analytics within energy-constrained environments would also offer valuable insight for firms in Sudan and similar emerging economies.

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APPENDIX: INTERVIEW GUIDE

➢ *Introduction to the Company and Production*

- Can you provide an overview of the company, its history, and its products?
- How has the implementation of automated sorting affected the company's production speed?

➢ *Automated Sorting*

- What role do automated sorting systems play in improving your business processes?
- How do these systems enhance efficiency and reduce the cost of logistics operations?
- Are you considering integrating other technologies, such as artificial intelligence or big data, with automated sorting?

➢ *Benefits and Economic Impact*

- How have automated sorting technologies influenced the company's profits or improved customer service?
- Has the technology helped create new jobs, and if so, of what kind?

➢ *Technical and Implementation Challenges*

- What technical challenges have you faced in implementing these systems?
- How have you dealt with maintenance and breakdowns?
- What are the most prominent technical problems you have encountered in using automated sorting systems?
- Are there challenges relating to quality control during sorting, and how is accuracy ensured?
- Can systems be modified or improved after a breakdown, and how is periodic maintenance handled?

➢ *Interaction with Logistics*

- How does automated sorting enhance shipping and distribution?
- Does automated sorting reduce human error in packaging or shipping?
- What advice do you have for small businesses considering adopting these systems?

➢ *Open-Ended Questions*

- How do you expect automated sorting technologies to evolve, and which advances do you think will most affect your operations?
- How has the implementation of automated sorting changed the daily routines and job satisfaction of your employees?
- How adaptable are your systems to changes in product type or volume, and what customisations have you made?