| RESEARCH ARTICLE

Data-Driven Automation: How Robotics and BI Reshape Retail Supply Chains in the United States

1) Kazi Obaidur Rahman, MBA (Business Analytics), Gannon University, Erie, Pennsylvania, USA. https://orcid.org/0009-0001-3548-4370
2) Songeta Dhar, DBA (Doctor of Business Administration), Westcliff University, Los Angeles, California, USA.
3) Shamimur Rahman, MBA in MIS, International American University, Los Angeles, California, USA.
4) Achhia Khanam, MBA in Accounting & Business Analytics, Maharishi International University, Fairfield, Iowa. https://orcid.org/0009-0007-1316-0467
5) Farhan Nasrullah, MBA (Business Analytics), Gannon University, Erie, Pennsylvania, USA. https://orcid.org/0009-0007-0984-8998
6) Mehedi Hasan, MBA, American International University, Dhaka, Bangladesh. https://orcid.org/0009-0004-6369-3462
7) Amir Hamza Akash, MSc. (Statistics & Analytics), University of Arkansas, Fayetteville, Arkansas, USA. https://orcid.org/0009-0003-7095-0896
8) Md Ashiqur Rahman Khan, Executive MBA (Management), University of Dhaka, Dhaka, Bangladesh.

Correspondent author: Kazi Obaidur Rahman, **e-mail**: sohagfinance@gmail.com

| ABSTRACT

Leveraging BI (Business Intelligence) with Robotic system in the distribution centers has become the game changer for U.S. retail domain. As the retail industry evolves with growing e-commerce business, complexity in supply chains, the integration of robotics and business intelligence (BI) tools play key role for operational transformation. BI-powered robotic systems in retailer's fulfillment centers and in-store can empower retailers in various ways like faster order processing and last-mile delivery, reduce delivery delays, optimizing supply chains, real-time business insights and so on. This article explores how data-driven automation reshapes retail supply chains through enhanced efficiency, real-time analytics, and intelligent forecasting. Here, we have taken real-world use cases like Target, Walmart and Amazon to see how they integrated BI-powered robotic systems in their distribution/fulfillment centers and highlighted how robotics streamline warehousing and delivery, while BI platforms enable smarter inventory management and strategic decision-making. We have developed an interactive dashboard containing KPI matrix for optimizing retail supply chain, which can be integrated with robotic system. The research also addresses challenges like high capital investment, data integration, cybersecurity, and workforce adaptation and offers a forward-looking perspective on the role of AI-powered robotics and automation in shaping the future of U.S. retail logistics.

1.0   Introduction:

Today's U.S. retail landscape has become more competitive, fast-paced and technology-driven digital platforms. To stay competitive and become successful, retailers need to invest in adapting BI-powered robotic systems to optimize supply chains in their distribution centers and in-store environments. As the retail industry is driven by evolving consumer expectations,

omnichannel demands, and technological advancement, retailers need to develop and manage well-equipped logistics, tech-based warehouses, and faster delivery systems to cope with growing demands. The integration of business intelligence tools with robotic systems in the distribution centers can be a data-driven automation solution for retailers that enable them to optimize operations, reduce costs, and enhance customer satisfaction.

Robotic system automation in retail supply chains has revolutionized the material handling process, order fulfillment cycle, last-mile delivery logistics, faster delivery and precision to traditionally labor-intensive tasks. Business Intelligence platform enabling retail managers with data-driven, real-time business insights across supply chain touchpoints. Therefore, the integration of robotic system and BI tools creates a smart, interconnected ecosystem where physical operations are continuously informed and optimized by digital intelligence.

This research article investigates how robotics and BI are reshaping retail supply chains in the U.S. by considering real-world retail business examples such as Target, Amazon, and Walmart. Through this exploration, we aim to highlight the strategic value of automation, the role of predictive analytics in supply chain management, and the emerging trends that signal the future of smart retail logistics.

2.0   Literature Review:

The U.S. retail industry plays the key role for the nation's economy, continues to evolve in technological disruption, dynamic market forces, and shifting consumer's choice, preferences. The U.S. retail sector contributed sales revenue of over $7.2 trillion in the U.S. economy during the period ended 2024 (Rahman et al., 2025). We see the tech-integrated business and omnichannel platforms yield higher customer lifetime value. In the post-covid period, we experienced a significant rise of omnichannel platforms, a combination of physical and online sales, to attract potential consumers by offering them personalized customer experience (Rahman et al., 2025). From the figure_01, we see the sales revenue of U.S. retail sector has been increasing over the periods from Y1992–Y2025 with a significant increase in post-covid pandemic with the increasing application of technologies like business intelligence tools, robotics, AI, ML etc. Therefore, retailers are heading towards omnichannel sales, i.e., online and in-store sales.

Figure_01: Advance monthly sales revenue for retail & food services from Y1992–Y2025.
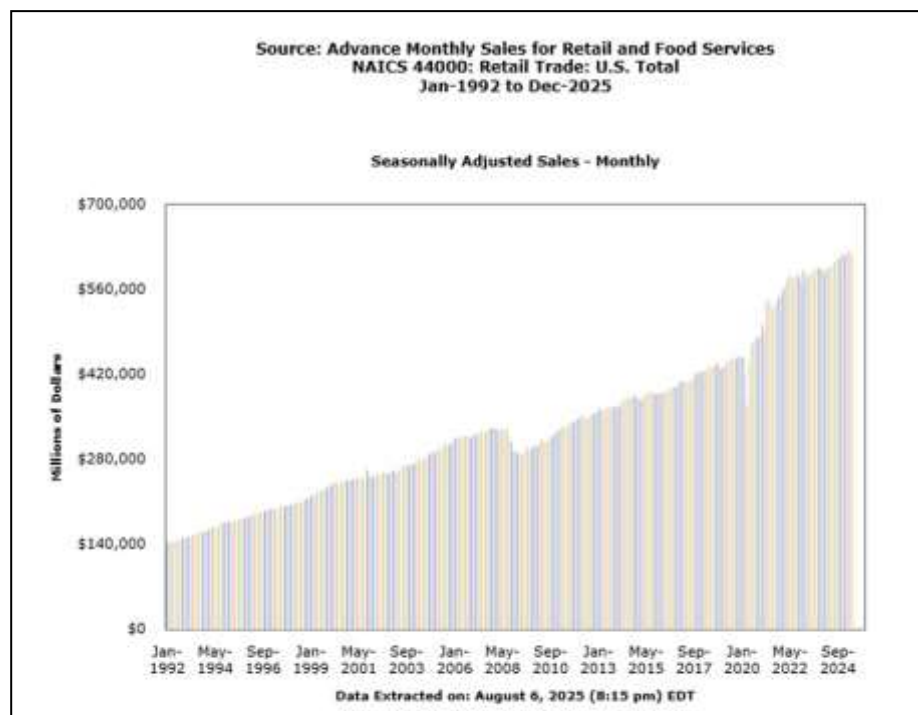
(Source: *Census.gov | U.S. Census Bureau*)

Business Intelligence technologies, robotics and their applications are becoming eminent part of today's business world which enriches business firms with sufficient information for taking data-driven strategic business decisions (Rahman et al., 2025). BI-

powered robotic system can contribute significantly to increasing sales revenue by reducing delay time, faster delivery, forecasting demand, and better customer experience. Therefore, the growth in revenue streams can be expedite by the implementation of business intelligence with robotic system (Rahman et al., 2025). Customer experience remains one of the most important factors influencing the sustainable growth of retail domain in the current business climate. Business Intelligence offers retailers the option of tailoring promotional messages and products, thereby increasing loyalty and sales (Rezvi et al., 2025).

2.1 Robotics in Supply Chain

In recent years, with the advancement of cutting-edge technologies, retailers are more likely to adopt robotics in optimizing supply chain. The demand for faster fulfillment, increasing labor costs, and optimizing logistic support have driven retailers to employ robotics in their supply chain process. Today, robotics play every role from AS/RS (automated storage and retrieval systems) in modern warehouses to transport products by AMRs (autonomous mobile robots).

2.1.1 Warehouse Automation

In modern warehouse management systems, retailers intend to rely on AMRs (Automated Mobile Robots) for their warehouse automation process. E-commerce giant Amazone have pioneered for warehouse automation by using robotics called "Kiva robots" also known as Amazone Robotics that transport shelves of inventory directly to human pickers within warehouses, reducing walking time and increasing picking speed, as well as improving efficiency and order accuracy. They are a key component of Amazon's fulfillment centers and have contributed to the company's ability to handle massive order volumes, especially during peak seasons. Other retail giants like Walmart and Kroger also implemented robotic automation in their warehouses. Even SME (Small and Medium Enterprise) type retailers are also automating their warehouses via third-party providers such as Geek+ and Locus Robotics.

Retailers can benefit from the use of warehouse robotics in various ways, for instance, it increases throughput and order accuracy, lowers dependency on human labor in repetitive tasks, enables retailers efficient space utilization through vertical storage solutions.

2.1.2 Robotic Fulfillment Centers

E-commerce retailers are more likely to invest in robotic MFCs (Micro-fulfillment Centers) which are designed for automation in delivery process following the consumer demands for same day delivery. Walgreen and Albertsons are the test cases for robotic fulfillment centers for faster processing online grocery orders.

2.1.3 Last-Mile Automation

Last-mile delivery process remains a challenge, and expensive legs of e-com retailers' supply chain. To automate the delivery process online retailers are now investing in innovative technologies like delivery robots and drones. Companies like Starship Technologies and Nuro have partnered with U.S. retailers to pilot self-driving delivery robots in urban areas, aiming to reduce delivery costs and increase speed for customers.

2.2 Robotic System: Challenges

Though there are substantial benefits to using robotics in supply chains process, there are still some challenges, and limitations for implementing robotic technologies. First, it requires high initial investments for the retailers and takes longer ROI timeline. Retailers need to develop robust IT infrastructure and integrate with its legacy systems as well as employ upskilled workforce.

Despite these hurdles, the trend is clear: robotics is becoming an integral component of retail supply chain strategy, enabling businesses to meet modern logistical demands with precision and scalability.

2.3 BI in Retail Supply Chains

Retailers use technologies like business intelligences tools, robotics, AI, and blockchain technology to optimize their supply chains (Rahman et al., 2025). While robotics brings physical automation to logistics and fulfillment, Business Intelligence (BI) delivers the analytical foundation that drives strategic decision-making. In the context of the U.S. retail supply chain, BI enables businesses to monitor, predict, and respond to operational variables in real time—transforming data into actionable insights.

2.4 Role of BI in Supply Chain Optimization

Business Intelligence platforms like Microsoft Power BI, SAP BusinessObject, Tableau and Oracle BI help retailers to consolidate raw data from various sources including sales platforms, inventory systems, logistics networks, and IoT-enabled robotics. BI tools transform these raw data into actionable insights in critical KPI matrix, and facilitate retailers with visualizations on interactive dashboards, reports, predictive models helping supply chain managers for taking strategic business decisions. BI platform empowers retailers to track and monitor KPIs including inventory turnover ratio, stockout, over/under stocking, lead time, EOQ level, reorder quantity & level etc. BI also helps forecast demands using historical sales data and seasonal trends.

3.0 KPIs for Retail Supply Chain

Table_01 exhibits retail supply chain KPI matrix for a typical retail business which includes inventory turnover ratio, on-time delivery rate, cycle time, demand forecasting accuracy, warehouse productivity etc. We will create an interactive dashboard based on this crucial KPI matrix.

Table_01: KPIs (Key Performance Indicators) retail business

KPIs	Measures/Function
Inventory Turnover Ratio	Measures how quickly stock is sold and replaced
On-Time Delivery Rate	Tracks the percentage of orders delivered on time
Order Cycle Time	Assesses time from order to delivery
Forecast Accuracy	Compares projected demand vs. actual demand
Warehouse Productivity	Evaluates efficiency of robotic and human labor

Here, we have developed an interactive dashboard for optimizing the retail supply chain. In figure_02, we designed a dashboard with KPI marrix including a table measuring actual verses target KPIs, and some cards with gauges for measuring the supply chain operational perfromance. In the dashboard, there are five cards displaying the actual performance, and the guages show the comparisons between the actual and target KPIs. This BI-powered interactive dashboard can be integreated with the robotic systems working in distribution/fulfillment centres for operational efficiency, accuracy, and optimizing inventory.

Figure 02: Dashboard exhibits KPIs for optimizing retail supply chain.

4.0   Descriptive, Predictive and Prescriptive Analytics

As technologies evolve over time, modern BI platforms go beyond descriptive analytics to facilitate predictive (forecasting) insights and prescriptive analysis. For instance, BI tools can help retailers to anticipate stockout situation by analyzing revenue trends as well as weather patterns. BI can also help find inventory reorder point by considering warehouse capacity and suppliers' lead time. It can also prescribe optimal/best delivery routes by analyzing real time traffic data.

If we look at Walmart supply chain system, we see, they use advance BI platform to monitor everything from vendor performance to store shelf availability. Walmart's BI system enables localized decision-making by consolidating data across thousands of stores and warehouses. The integration of business intelligence and robotics allows real-time inventory adjustments as autonomous shelf-scanning robots identify empty slots.

5.0   Leveraging BI with Robotics

The true potential of automation in U.S. retail supply chains lies not only in robotics or business intelligence (BI) alone, but in their integration. When robots generate real-time operational data and BI tools analyze and visualize it, the supply chain becomes a smart, self-correcting ecosystem that supports both operational efficiency and strategic agility.

5.1 Decision-making based on real-time insights

Retail investors are more likely to invest in developing business intelligence dashboards connected to robotic systems, which enable business managers to monitor robotics' performance in real-time warehouse environment and make data driven decisions based on business insights. BI dashboard provides retailers with valuable insights into warehouse KPIs (Key Performance Indicators) for measuring business performance in supply chains using robotics. Robots equipped with sensors and RFID trackers can report inventory levels, bin accuracy, and system failures directly into BI platforms.

5.2. Predictive Analytics

Business intelligence can be used to predict robotic system malfunctioning prior to any incidence. For instance, Amazone uses BI platforms for its fulfillment centers to monitor and predict wear-and-tear conditions of robots, alert them in advance for schedule maintenance, which reduces down-time and increases robotic systems lifespans.

5.3 Intelligent Inventory Management

In business intelligence with robotic platform systems, when robotic picking systems feed SKU movement data into BI models, retailers get a live view of inventory turnover and stock levels. BI in inventory management system enables retail managers to automate reorder point suggestions, product assortment optimization by region, adaptive stocking strategies for peak seasons etc.

5.4 Advantages of BI with Robotics:

Retailers can avail numerous benefits from the integration of business intelligence tools with robotics in their distribution centers. This integrated system can enhance operational visibility, which increases end-to-end supply chain transparency in fulfilment centers. It also helps retailers gain operational efficiency by eliminating human oversight and reducing lag times. Moreover, it benefits from scalability, i.e., easily replicable systems across multiple warehouses or different locations. Therefore, retailers can increase customer satisfaction index by providing faster, accurate and timely deliveries to their respective customers.

6.0   Real-World Use Cases:

In this article, we have considered real-world retail examples such as Target, Amazon, and Walmart to highlight the strategic value of automation, the role of predictive analytics in supply chain management, and the emerging trends that signal the future of smart retail logistics.

6.1. Target: BI with Robotics

The retail superstore Target uses custom-built business intelligence tools integrated with robotic system in their distribution centers for efficient warehouse management, optimized shipment speed, accuracy in order processing and delivery system. Target's intelligent supply chain management system can identify any delays and reroute packages automatically. The integration of business intelligence with robotic system in Target's distribution centers has improved fulfillment times, reduced last-mile delivery failures.

6.2. Amazon: Robotics-Driven Fulfillment Centers

Amazone is considered as the pioneer of U.S. retail for integrating cutting-edge technologies in its logistics. Its fulfillment centers are well equipped with BI-powered robotics. The company acquired Kiva System (Amazone Robotics) and deployed more than 750,000 robots in its fulfillment centers. These robots are used to transport inventory/products to human packers, communicate data to BI engine, AI, and ML to predict product demands, and optimize delivery routes, and helps ensuring same day or next day delivery promises. By using these modern technologies, Amazon has reduced 50% of its order processing time, improved accuracy and real-time inventory tracking, optimized its supply chain.

6.3. Walmart: Smarter Warehousing

Walmart has integrated robotic system with business intelligence not only in its warehouses, but also in their stores across the country. Self-scanning robots are deployed for navigating and checking for price accuracy, and availability of products instore shelves. This data is fed into Walmart's internal BI platform, which integrates insights from robotics with POS, vendor systems, and logistics channels. The integration of BI with robotics facilitates Walmart with real-time visibility to see if the products are available in the store, demand forecasting accuracy, and faster restocking and fewer customer stockouts.

7.0   Challenges and Limitations

Despite the transformative potential of robotics and business intelligence (BI) in U.S. retail supply chains, their implementation is not without hurdles. Retailers must navigate a range of technological, organizational, financial, and ethical challenges to realize the full benefits of automation and data-driven operations.

7.1 High Capital Investment

The installation and integration of business intelligence platform with robotics requires significant initial capital investment. The integration process is comprised of specialized hardware, customized software, IT infrastructures, license fees, trained employees etc.

7.2 Data Integration Complexity

Business intelligence and robotics should interface with legacy retail platforms, such as WMSs, POS systems, ERP systems. Any inconsistency in data formats and data silos may cause delaying data integration process, inaccurate data analytics, poor quality real-time visibility. Therefore, retailers need to establish strong data processing governance, unified architecture for data engineering, where many retailers are still evolving.

7.3 Cybersecurity and Privacy Risks

Retailers need to invest in robust cybersecurity protocols and compliance strategies for protecting customers or operational data against cyberattack, because automated and connected systems introduce vulnerabilities. Robotic systems and BI dashboards are susceptible to cyberattacks or data breaches

7.4 Technological Limitations

Despite advanced robotic system development, there are still some limitations in retail environments like complex nature of SKUs, fragile products, irregular items shape which require human handling, monitoring. BI tools and its applications require proper training or simplified dashboards for data-driven decision making, otherwise it may provide overwhelming outcomes.

8.0   Retail Industry Outlook:

As robotics and business intelligence (BI) technologies continue to evolve, the future of U.S. retail supply chains points toward full autonomy, real-time intelligence, and predictive decision-making. This evolution is not just a matter of efficiency, it represents a foundational shift in how retail businesses operate, innovate, and compete.

8.1 AI-Powered Robotics

Retailers are intended to rely on artificial intelligence and machine learning tools to automate their warehouse and delivery robots, which enables them to advance object recognition and product handling, context-aware decision-making process, self-learning navigation system. In future, AMRs (Autonomous Mobile Robots) will dominate warehouse environments, while AI-driven drones and delivery bots take over last-mile fulfillment in dense urban areas.

For effective implementation of AI-powered Robotics in warehouse and in-store environments, we need trained and skilled workforce in places. AI can also help the retail sector tackle its HR problems with well expanded recruiting processes, personalization of training, and to enhance performance management (Rezvi et al., 2025).

8.2 Edge Analytics and IoT Integration

The next-gen business intelligence platform will focus on edge analytics leveraging with IoT-enabled devices, which process raw data closer to the data sources, such as, sensors on shelves or robots. This will provide retailers with instant business insights from raw data at source, without relying on cloud latency. Retailers would be able to detect any local anomaly such as inside temperature deviations, any malfunction in robotic system etc. The IoT-enabled edge analytics system helps businesses run through more efficient energy and resource management.

8.3 Human-Machine Collaboration

Though retailers focus on full automation in some areas, human handing/expertise will require handle issues involving decision-making, customer care roles, exception handling etc. Therefore, retail investors are more likely to invest in HMI (Human-Machine Interface) model, AR (Augmented Reality) for operational training, and skill-up programs for employees to handle hybrid roles of human-machine collaboration.

8.4 Future Strategic Imperatives

With the advancement of technology and digital platforms retailers are facing increased pressure from their competitors. Therefore, to stay competitive, retailers should set their business strategies powered by AI-driven business intelligence architecture, install and utilize robotics in their logistic system, develop consumer-centric supply chain models, equipped with multifunctional IoT-enabled platform.

The retail supply chain of the future will not be just faster or cheaper, it will be smarter, more sustainable, and more resilient. The convergence of robotics and BI will enable retailers to move from reactive problem-solving to proactive orchestration of every step in the supply chain journey.

9.0   Conclusion

The integration of business intelligence and robotic system virtually reshaping the landscape of U.S. retail supply chains following the consumer demands, expectations and technological advancements. This integration enables retailers with data-driven automation in the supply chain process which drives operational efficiency, agility and consumer satisfaction. Robotics-driven automation in retail supply chains has transformed significantly the material handling process, order fulfillment efforts, faster last-mile delivery logistics, and precision to traditionally labor-intensive tasks. In addition, business intelligence tools enabling retail managers with data-driven insights across supply chain process for taking strategic decision-making. In this article, we have developed a realistic and interactive dashboard for the retail supply chains by applying business intelligence

tools like power BI, which can be integrated with robotic systems to establish a smart, interconnected ecosystem where physical operations are continuously informed and optimized by digital intelligence.

Throughout the article, we have illustrated (considering real-world retail use case examples) how leading retailers are leveraging robotics and BI not as isolated tools but as interdependent drivers of transformation. However, we have outlined and explained some challenges like high initial investment, data integration hurdles, and the need for workforce reskilling, which need to be addressed proactively.

In future, U.S. retail supply chains lies in AI-driven automation, edge analytics, and hyper-personalized, sustainable logistics. Retailers who embrace this convergence will not only streamline their operations but also position themselves as leaders in the next generation of commerce.

Funding: This research received no external funding.
Conflicts of Interest: The authors declare no conflict of interest.
Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers.

References

[1] Amazon. (2023). *How Amazon Robotics is transforming fulfillment*. Retrieved from https://www.aboutamazon.com

[2] Croxton, K. L., García-Dastugue, S. J., Lambert, D. M., & Rogers, D. S. (2001). The supply chain management processes. *The International Journal of Logistics Management, 12*(2), 13–36. https://doi.org/10.1108/09574090110806271

[3] Rahman, K. O., Islam, M. S., Rezvi, R. I., Hasan, M., Khanam, A., Nasrullah, F., … & Akash, A. H. (2025). AI-Driven Next-Gen US Retail: An Empirical Study on Optimizing Supply Chains by leveraging Artificial Intelligence, Business Intelligence, and Machine Learning. Journal of Computer Science and Technology Studies, 7(1), 258-264. https://doi.org/10.32996/jcsts.2025.7.1.19x

[4] Rahman, K. O., Rezvi, R. I., Nasrullah, F., Islam, M. S., Hasan, M., Khanam, A., & Akash, A. H. (2025). Business Model Canvas: Business Analytics on Gas stations with C-stores in United States. Journal of Business and Management Studies, 7(1), 180-185. https://doi.org/10.32996/jbms.2025.7.1.13

[5] Rahman, K. O., Hasan, M., Khanam, A., Nasrullah, F., Mia, M. M., Jishan, S. S., & Rezvi, R. I. (2025). Investment & Market Growth Analysis: Insights into US Retail Stock Performance, Emerging Players, M&A Trends. Journal of Economics, Finance and Accounting Studies, 7(3), 112-117. https://doi.org/10.32996/jefas.2025.7.10

[6] Rezvi, R. I., Rahman, K. O., Nasrullah, F., Islam, M. S., Hasan, M., Nusrat, N., … & Ahmed, S. (2025). The integration of artificial intelligence in human resource management in the US retail sector. Journal of Business and Management Studies, 7(1), 273-278. https://doi.org/10.32996/jbms.2025.7.1.22

[7] Rahman, K. O., Khanam, A., Hasan, M., Akash, A. H., Rezvi, R. I., Nasrullah, F., … & Nusrat, N. (2025). Decoding US Retail Dynamics: A Holistic Strategic Analysis Using PESTEL and Porter's Five Forces Frameworks. *Journal of Business and Management Studies*, *7*(2), 176-183. https://doi.org/10.32996/jbms.2025.7.2.12

[8] Rahman, K. O., Akash, A. H., Hasan, M., Nasrullah, F., & Khanam, A. (2025). Navigating business intelligence: Analyzing and visualizing KPIs of US gas stations with C-store by applying MIS, BI tools charts, graphs, interactive dashboards. *Edelweiss Applied Science and Technology*, *9*(8), 1354-1367. https://doi.org/10.55214/2576-8484.v9i8.9610

[9] Rezvi, R. I., Hasan, M., HASAN, M. A., Protik, M., Nasrullah, F., Ahmed, S., … & Rahman, K. O. (2025). Data-Driven Persona: How Business Intelligence Analytics Enhance Customer Experience for US Small and Medium Enterprises (SMEs). *Journal of Computer Science and Technology Studies*, *7*(9), 196-201. https://doi.org/10.32996/jcsts.2025.7.9.24

[10] Kroger. (2022). *Kroger and Ocado: Building the future of grocery e-commerce*. Retrieved from https://www.thekrogerco.com

[11] Lee, H. L., & Ryu, K. S. (2021). Intelligent automation in the supply chain: A review and research agenda. *Journal of Business Logistics, 42*(2), 176–192. https://doi.org/10.1111/jbl.12263

[12] Microsoft. (2023). *Retail supply chain insights with Power BI*. Retrieved from https://powerbi.microsoft.com/en-us/blog

[13] Ocado Group. (2023). *Technology and automation for the future of grocery*. Retrieved from https://www.ocadogroup.com

[14] Target. (2023). *Inside Target's smart supply chain*. Retrieved from https://corporate.target.com

[15] Walmart. (2023). *Walmart's automation and supply chain transformation*. Retrieved from https://corporate.walmart.com

[16] Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent manufacturing in the context of industry 4.0: A review. *Engineering, 3*(5), 616–630. https://doi.org/10.1016/J.ENG.2017.05.015

[17] Bar Chart: Monthly Sales, as on August 20, 2025 (11.45pm) EDT, Census.gov | U.S. Census Bureau, Business and Industry: Time Series / Trend Charts