Enhancing Accuracy and Efficiency in Physical Count Processes: Leveraging AI, IoT, and Automation for Real-Time Inventory Management in Supply Chain

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Abstract: This paper aims at studying how much AI, IoT, and automation play a crucial role in improving the calibration and effectiveness of physical inventory count exercises. As supply chain networks become enhanced, companies are using these technologies to counter issues that come with the use of enhanced inventory control including but not limited to errors, slowness among others. About this, the present paper examines two different case studies one, based on a well-known logistics company in Finland, and the other, Amazon's fulfillment centers exploring how the application of AI, IoT and automation enhance real-time inventory management. The study informs that the adoption of these technologies greatly improves both the integrity and efficiency of inventory data, accurate real-time monitoring, and less reliance on manual adjustments, and streamlines warehouse logistics. This paper fills the existing literature gap in understanding technological advancements in inventory management and provides valuable recommendations to companies that wish to transform in the context of the Fourth Industrial Revolution.

1 INTRODUCTION

1.1 Overview

In today's dynamic business world, inventory control has emerged as one of the key aspects in determining business effectiveness in delivering timely goods and services that meet the customer' s expectations . Such manual ways of conducting physical inventory counts as a basic approach is a bit slow and can have a high incidence of errors (Mermi, 2024). Below figure 1 illustrates the four industrial revolutions. The first revolution (1784) was powered by steam engines, revolutionizing manufacturing and transportation. The second (1870) harnessed electricity, enabling mass production. The third (1969) introduced information technology, transforming communication and data processing. The ongoing fourth revolution is driven by artificial intelligence, shaping the future of automation, innovation, and decision-making.

When organizations grow and there is a demand for rapid data flow, the continuous utilization of manual handling of inventory records is counterproductive (Ugbebor, 2024). To deal with these challenges

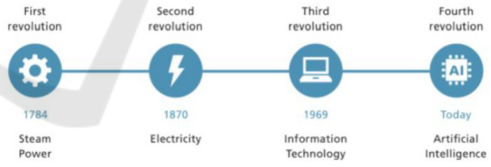

Figure 1: The industrial revolution (Dinh,2020).

Companies are seeking innovative solutions that are AI, IoT and automation. All these technologies are likely to bring about enhanced accuracy of the inventory management processes coupled with efficiency gains (Ayoola, 2024). The current research aims at establishing how physical inventory count can be improved using AI, IoT and automation to provide real-time inventory updates thus minimizing costs and improving the supply chain.

1.2 Background

Conventional physical inventory taking procedures involve tasks such as estimating quantities via stock

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counts which are done by employees; this is unproductive, cumbersome and may lead to inaccuracies. These manual techniques cause inconsistencies in stock data thus causing stock out, overstocking or incorrect records in the financial accounts. In addition, the increasing scale of business operational hampers the accuracy of inventories records and the extent of its update. Hence, companies are looking for ways of increasing accuracy of the inventory and enhance the effectiveness of such a procedure. Below figure 2 represents the key stages of warehouse operations. It begins with unloading and receiving goods, followed by the put-away process, where items are stored in designated locations. Next, goods are organized in storage until needed. When an order is placed, the order-picking stage retrieves the required items. Finally, products are packed and loaded for shipment to their destination.

Figure 2: Warehouse operation process .

1.3 Significance of the Study

Effective resource management is essential to meeting consumer needs without overstocking or incurring high operating costs (Kumar, 2024). Real-time inventory tracking allows businesses to make informed decisions on restocking, supply chain management, and demand forecasting (Vinolyn Vijaykumar, 2024). Inventory mismanagement can directly impact customers, particularly in industries reliant on tendering of products (Vaka, 2024). Integrating AI, IoT, and automation presents a viable solution for improving inventory accuracy and overall business performance(Dash, 2019).

This study explores how these technologies enhance traditional inventory management, offering valuable insights into their impact on efficiency, decision-making, and operational effectiveness in modern supply chain processes.

1.4 Technological Context

Artificial Intelligence (AI), the Internet of Things (IoT), and automation are at the forefront of technological advancements in inventory management. AI uses machine learning algorithms to analyze inventory data, predict demand, optimize stock levels, and detect anomalies in real-time (Khan, 2024). IoT enables businesses to track inventory using smart sensors and RFID (Radio Frequency Identification) tags, allowing for seamless and real-time updates on inventory levels (None Shivam, 2024). Automation, such as the use of drones or robotic systems for physical counting, reduces human intervention, increases speed, and minimizes the chances of errors. These technologies work in tandem to provide a more accurate, efficient, and automated approach to managing inventory, making them crucial for modern businesses looking to streamline their operations (Vigneshwaran Gowrishankar, 2024).

1.5 Research Questions

- How can AI, IoT, and automation enhance the accuracy of physical inventory count processes?
- What efficiency improvements can be achieved through real-time inventory management using these technologies?

2 LITERATURE REVIEW

Inventory control has long been a crucial aspect of supply chain and operations management, emphasizing the importance of maintaining optimal stock levels to meet customer demand efficiently and cost-effectively. Traditionally, businesses relied on manual processes such as Excel spreadsheets or periodic stock counts, which proved error-prone and inefficient (N. Kargah-Ostadi, 2020). Over time, models like Economic Order Quantity (EOQ) and Just-in-Time (JIT) have been introduced to optimize inventory while minimizing holding and ordering costs. However, many industries still rely on manual procedures. Today, advanced technologies such as AI, IoT, and automation are beginning to transform inventory management, enhancing accuracy and efficiency (Soori, 2023).

AI, IoT, and automation have revolutionized inventory management. Machine learning and predictive analytics enhance demand forecasting by identifying stock patterns. IoT enables real-time inventory tracking through RFID tags and sensors, providing instant stock updates (Mukherjee, 2021). Automation technologies like drones and robotics are increasingly adopted for stocktaking, reducing errors and speeding up inventory counting processes

2.1 Technological Integration

Numerous studies highlight how AI, IoT, and automation enhance inventory control. AI-driven

predictive models analyze demand fluctuations, optimizing inventory replenishment timing and storage allocation (Kumar, 2024). For instance, machine learning can process past sales data to forecast future demand accurately, minimizing stockouts and overstocking. IoT enables real-time inventory tracking, offering a more efficient approach to inventory and supply chain management. Research indicates that RFID-based IoT systems provide systematic, real-time stock updates while reducing human errors in inventory control. These technologies collectively improve accuracy, efficiency, and decision-making, making them essential for modern inventory management and supply chain optimization (Dash, 2019).

Automation has significantly improved efficiency in large-scale warehouses. Drones and robots streamline stocktaking, reducing labor reliance while enhancing speed and accuracy (Vigneshwaran Gowrishankar, 2024). Research indicates that automated systems improve inventory counting accuracy by 40% over manual methods. These technologies provide real-time inventory insights, enabling better decision-making, optimizing operations, and ultimately enhancing customer satisfaction.

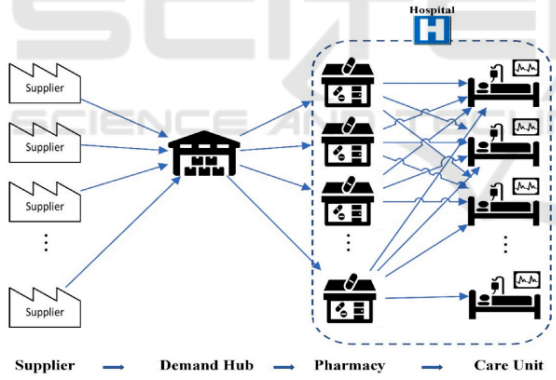

Figure 3: Flow of medical supplies (Mermi, 2024).

2.2 Gaps in Literature

Currently, there is a vast amount of literature that discusses the individual technologies – AI, IoT, and automation; however, theoretical research and case studies on the application of these technologies are abundant (Vaka, 2024). However, there is a lack of published work presenting combined effects of both on the physical inventory count processes, more so from the perspective of real-time inventory count (Ayoola, 2024). More literature reviews are confined to single technology or existing sectors where technological processes have been undertaken, while a research gap exists regarding how these technologies operate simultaneously to mitigate the issues that arise with physical inventory counts (Olugbenga Madamidola, 2024).

In addition, many studies examine IoT and automation in manufacturing efficiency, few focus on their impact on physical stock counting in inventory management (Mukherjee, 2021). Existing literature lacks insights into how these technologies enhance accuracy and efficiency in near-real time, leaving gaps in understanding their full potential for inventory optimization.

Existing literature extensively examines AI, IoT, and automation individually, with numerous theoretical studies and case analyses on their applications. However, there is a significant research gap regarding their combined impact on real-time physical inventory counting. Most studies focus on single technologies or specific industries, offering limited insights into their integrated potential. While some research explores IoT and automation in operational efficiency, few analyze their direct role in improving stock counting accuracy. Additionally, the absence of a proposed novel approach for real-time inventory tracking restricts practical advancements. These gaps hinder the development of actionable insights needed to optimize inventory management practices.

3 METHODOLOGY

Case Study (Dinh, 2020)**: AI in Inventory Management at Finnish Logistics Company**
This paper examines a Finnish logistics company that has implemented AI in warehouse inventory management, integrating Machine Learning (ML) and Deep Learning (DL) to optimize supply chain processes. AI has improved real-time inventory tracking, replenishment accuracy, and efficiency. Using a quantitative approach, data was collected through employee interviews. The study evaluates AI's impact on inventory accuracy, efficiency, and employee awareness while analyzing its strengths, weaknesses, opportunities, threats, and future prospects in inventory management.

Case Study (Mermi, 2024)**: AI and Robotics in Amazon's Fulfilment Centres**
Amazon's use of AI in its fulfillment centers exemplifies how technology can revolutionize inventory management. The company employs robotics, automated guided vehicles (AGVs), and advanced automation for movement control, order picking, restocking, and inventory tracking. By

maximizing operational capacity, Amazon has achieved exceptional accuracy in handling vast inventories, setting international supply chain management standards. This case study, based on secondary research from online databases, press releases, industry reports, and academic journals, highlights AI's role in enhancing warehouse efficiency. The study focuses on how robotics and automation streamline inventory processes, improving speed, accuracy, and real-time stock control while reducing human dependency. Additionally, it explores how other firms can replicate Amazon's AI-driven strategies to optimize their own inventory management systems.

3.1 Comparison of Case Studies

The two case studies present different but complementary perspectives on the integration of AI into inventory management. While both companies utilize AI, IoT, and automation, their approaches and implementations vary significantly due to the differences in scale, industry, and technological infrastructure.

1. Technological Scope:

- **Finnish Logistics Company:** The focus is primarily on AI-driven solutions like machine learning and deep learning to enhance inventory control. The case highlights the challenges of adopting AI in a more traditional logistics environment.
- **Amazon:** In contrast, Amazon has a much broader implementation of AI, integrating robotics, AGVs, and AI algorithms in its fulfillment centers. This allows for more advanced automation, enabling higher levels of real-time tracking and inventory accuracy.

2. Impact on Inventory Management:

- **Finnish Logistics Company:** The integration of AI has led to notable improvements in inventory accuracy and operational efficiency. However, challenges remain in the form of employee adaptation to AI-driven changes, which will likely improve over time.
- **Amazon:** AI has been successfully applied to virtually all aspects of inventory management, with a strong emphasis on robotics and automation. The company's fulfillment centers represent a highly efficient and scalable model for real-time inventory management.

3. Scalability and Application:

- **Finnish Logistics Company:** While the company's adoption of AI is impressive, its scale is smaller compared to Amazon, and the focus is on improving efficiency and accuracy within a single logistics operation.
- **Amazon:** Amazon's global scale and use of cutting-edge robotics and AI technologies set it apart, with the company continuously innovating in warehouse automation and inventory management.

By comparing these cases highlights AI's diverse impact across companies. Both demonstrate AI's role in enhancing inventory precision and productivity, but Amazon represents large-scale automation with advanced robotics, a model difficult to replicate on a smaller scale. In contrast, the Finnish logistics company offers a more practical example of AI integration, showcasing challenges in adoption. Together, these cases illustrate how AI, IoT, and automation are transforming inventory management, improving accuracy, efficiency, and real-time tracking across different business scales.

3.2 Potential Challenges in Adopting IoT for Big Warehouses

Implementing IoT in large warehouses presents several challenges affecting efficiency and scalability. Latency and Connectivity Issues arise from weak signal coverage and network congestion, delaying inventory tracking. Scalability Constraints occur when integrating thousands of sensors and RFID tags across multiple warehouses, requiring infrastructure upgrades. Data Overload demands advanced cloud solutions and edge computing to manage vast real-time inventory data. Cybersecurity Risks increase with more IoT entry points, necessitating robust security. Integration with Legacy Systems poses compatibility challenges, hindering seamless IoT adoption. Maintenance and Reliability require continuous monitoring to ensure sensors and automated systems function without disrupting warehouse operations.

4 RESULTS

4.1 Findings of Case Study Results

Case Study (H. Dinh, 2020)**: AI-Driven Supply Chain Enhancement**

The data collected from the Finnish logistics company reveal several key findings related to the impact of AI on inventory management:

- **Improved Inventory Accuracy:** The use of AI in the form of machine learning and deep learning has improved inventory accuracy systems' to a great extent. Some of the improvements, which the company was able to note after implementing the change included; a marked decrease in the stock loss differences and human mistake that were prevalent during stock-take. Intelligent systems offered features for real time monitoring and prediction for physical inventory as well as their digital counterpart.
- **Efficiency Gains in Warehouse Operations:** Stock counting and replenishment has benefited form the efforts made to automate the processes that were once done manually. Optimization of the supply picking and replenishment routes has reduced the durations taken and turnover rates hence faster system operational rates.
- **Employee Adaptation and Awareness:** A survey with the employees showed that there was low to moderate understanding of AI implementation. Some responses that stood out include concerns about embracing change, and thus adjusting to new technology that brings improvement on the operational efficiency of organizations by use of AI. But the company ensured that employees undergo extensive training; the effects of such aspect were therefore reduced.
- **Challenges and Future Prospects:** In the implementation part, integration problems between new advanced AI technologies and organizations' existing systems were mentioned as a problem. But for the present, the company is hopeful about improving predictive capabilities of AI and about applying AI to more aspects of inventory management in the future.

Case Study (Mermi, 2024)**: AI and Robotics in Amazon's Fulfillment Centers**

Amazon's case study reveals a robust and advanced application of AI in its fulfillment centers

- **High-Level Automation and Accuracy:** This Company has embraced AI and robotics in every process, from storage, replenishment of stocks to picking of orders. Robotics has helped enhance the rate and accuracy of inventory with the support of AI to manage real-time data integration throughout the firm's network of fulfillment centers globally.
- **Scalability and Real-Time Inventory Management:** Robotics and automated systems, as well as utilized AI algorithms, help the company control significant amounts of inventory at different locations. Other outstanding features achieved through real-time Inventory Management include reduction of stockouts as well as cases of overstocking since Amazon gets to track its demand and supply levels in the most accurate manner possible.
- **Minimal Employee Interference:** While the AI and robots undertake most of the responsibilities, employees are still in charge of the running of the processes, monitoring, repair, and decision making. Precision of work whilst incorporating flexibility has been boosted by the use of artificial intelligence through adoption by Amazon.
- **Challenges and Future Opportunities:** It is also essential to mention some of the problems that Amazon faced in its AI/robotics journey, namely, high initial expenses at the end of which, the scaled-up value generated is considered, and the difficulty of synchronizing all the global centres of the company. The company's latest strategic direction in this regard is to work on improving integration between human employees and technology tools to provide better quality and adaptability.

4.2 Answer to Research Questions

RQ 1: How can AI, IoT, and automation enhance the accuracy of physical inventory count processes?

These case studies confirm that AI, IoT, and automation significantly enhance the precision of physical inventory counting. Machine Learning (ML) and Deep Learning (DL) improve inventory tracking by eliminating human errors and ensuring real-time stock data accuracy. The Finnish logistics company experienced fewer discrepancies between physical and virtual stock due to AI-based tracking. Meanwhile, Amazon's fulfillment centers leverage robotics and AI to provide accurate real-time stock updates, reducing errors associated with manual labor. These technologies streamline replenishment, picking, and order fulfillment, ensuring accurate stock flow and optimal decision-making while minimizing costly inventory mistakes. Figure 4 illustrates AI's role in Amazon's warehousing operations. AI significantly enhances receiving, put-away, storage, and fulfillment processes, improving tracking and tracing to reduce errors. Robotics and automation further optimize picking and packing

operations, resulting in faster, more precise outcomes. Additionally, IoT devices provide real-time shipping and delivery data, enhancing customer experience and improving overall organizational efficiency in inventory management.

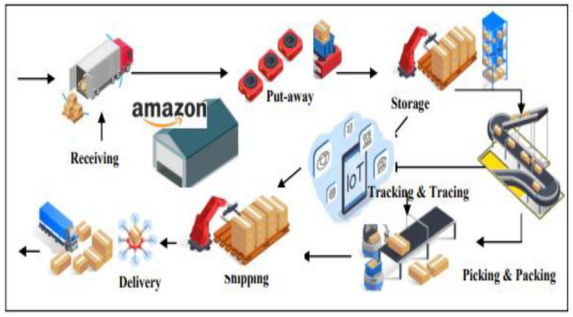

Figure 4: AI Technologies in Amazon's Warehouse.

RQ 2: What efficiency improvements can be achieved through real-time inventory management using these technologies?
Real-time inventory management, powered by AI, IoT, and automation, significantly boosts productivity. These technologies enhance stock tracking speed, data accuracy, and minimize downtime. Amazon's real-time inventory tool synchronizes global fulfillment centers, preventing stockouts and overstocking. Similarly, the Finnish logistics firm reduced costs through AI-driven inventory automation. These improvements enable faster decision-making, reduce manual labor reliance, and enhance responsiveness to inventory fluctuations, resulting in leaner operations and lower costs across warehouse management and supply chain processes.

5 DISCUSSION

5.1 Interpretation of Results

From the analyzed case studies highlight the value of AI, IoT, and automation in enhancing inventory accuracy and efficiency. Both the Finnish logistics company and Amazon demonstrate AI's impact on improving stock tracking. AI enables the Finnish firm to implement real-time inventory tracking and receive alerts for discrepancies between physical stock and system records. Amazon, leveraging AI, machine learning, and robotics, optimizes automation for precise inventory synchronization. By minimizing human intervention, these technologies ensure accurate stock updates, reducing errors and enhancing operational efficiency. Overall, AI-driven inventory management improves accuracy, streamlines operations, and enhances decision-making in modern supply chains.

In both cases, AI adoption required employees to adapt to new ways of working. Initially, Finnish logistics company employees resisted AI integration, but later developed a positive outlook. While AI reduced manual stocktaking, employees transitioned to strategic roles, such as monitoring AI systems and addressing issues. Similarly, Amazon's AI-driven robotics now handle most physical tasks, while human workers focus on system oversight and maintenance. This demonstrates that AI and automation do not replace human labor but redefine roles, shifting employees toward managing AI operations and making strategic decisions, ultimately enhancing workforce efficiency and technological collaboration.

5.2 Environmental Impact of IoT in Warehouses

The IoT adoption in warehouses increases energy use and e-waste. Continuous power is needed for sensors, RFID tags, and automation, raising electricity demand. High-powered data centers and cloud computing for real-time tracking to elevate the carbon footprint, while wireless networks and edge computing add to energy consumption for data processing and transmission.

IoT advancements lead to frequent device upgrades, generating e-waste. Hard-to-recycle sensors, batteries, and hardware contribute to environmental contamination, while short product lifecycles further intensify the challenge of sustainable disposal in warehouses.

To minimize these impacts, warehouses can implement energy-efficient IoT solutions, use recyclable materials in devices, and adopt sustainable e-waste management practices to reduce energy consumption and manage waste effectively.

5.3 Limitations

Despite the realization of AI, IoT, and automations lead to better inventory management, change implementation is not easy. In general, both case studies investigated the issues firms face when incorporating new technologies with legacy systems, which sometimes slows down the advantages that such technologies offer. They indicate the use of AI-based systems requires considerable time and resources modalities to be imparted in human resource dealing with them. Small companies will be

unable to invest in such technology and training thus putting them in a limited position as regards implementing these innovations.

Both case studies focus on large companies with the financial and organizational capacity to implement AI, IoT, and automation. Amazon, as the world's largest e-commerce firm, leverages AI at scale, benefiting from extensive technological resources. However, these findings may not be generalizable to smaller businesses with limited resources, making them more applicable to large or international firms rather than small and medium enterprises (SMEs).

6 CONCLUSION

6.1 Summary of Findings

The study focuses on AI, IoT, and automation as key factors that have revolutionized physical inventory count through their ability to improve the precision and speed of the processes in question. The proposed studies, based on the experience of a Finnish logistics company and Amazon, show that the use of AI and automation strengthens the efficiency of inventory management in terms of both precision and productivity. They facilitate real time tracking of products, minimize error and enhance efficiency of the warehouse through repetitive tasks to these technologies. This change of technology posed some barriers to development since the initial employees struggled to handle new systems, only to change their roles to managers of these complex solutions once they were able to adapt. Furthermore, both firms demonstrate that large organizations can find scalable solutions and that their success depends on these organizations' size and available resources.

6.2 Recommendations

Based on the findings, the following recommendations are made for organizations considering the integration of AI, IoT, and automation into their inventory management processes:

- **Gradual Integration:** To avoid the risks mentioned above, organizations should take a gradual approach when integrating AI and automation, beginning with using them in pilot projects or in some specific segments of company activity. It enables assessment and modeling depending on performance outcomes to incorporate changes to meet new demands.
- **Employee Training and Reskilling:** While deploying intelligence and automation technologies, organizations should ensure an adequate training plan to create staff ready to manage, operate and upkeep the technologies. The utilization of these tools will be easier and immediate if a workforce is already familiar with them.
- **Adaptation of Legacy Systems:** IT departments with legacy technologies already in place should think through how AI and automation will live alongside current inventory management systems. Perhaps instead of implementing completely new systems of working, replacement could come in a more integrated form where new technologies build upon and improve the existing structures.

6.3 Future Research

Future research should explore several avenues to deepen our understanding of AI, IoT, and automation in inventory management:

- **Broader Industry Exploration:** Engaging different industries and organization sizes to provide real-life case studies will give a clearer understanding of the opportunities and issues that revolve around AI and automation. In particular, more effort dedicated to scientific study of SMEs could offer means that such companies can use to overcome challenges related to implementing such technologies.
- **IoT's Role in Real-Time Inventory Management:** Even though this research provides a connection to IoT, it can be seen that further potential of IoT in real-time stock management was not investigated in this study. Subsequent research must explore the potential of IoT in creating bi-directional visibility of inventory across various systems and platforms to improve operational inventory flexibility.
- **Advanced AI Models and Predictive Analytics:** As artificial intelligence progresses there is opportunity to enhance inventory analytics through more advance predictive methods. Future research could aimed at how accurate demand forecasting models are and the application of these models

to enhance demand and supply management and hence minimize wastage.

Thus, extended investigation of these three prospective areas will allow researchers and practitioners to advance further the use of AI, IoT, and automation in inventory management, contributing to greater businesses opportunities in different industries.

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