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" Industrial Applications of AI in Warehouse Management: A Systematic Review of Drone Usage in Manufacturing "

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Firma (signature) MARZIEH KHATIBI……

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ABSTRACT

In this thesis, we study how artificial intelligence (AI) and drones can be used in tandem to enhance the efficiency and safety of modern warehouse management systems. It does this by collecting and analyzing a set of relevant studies found through a systematic literature review of sorts, carried out according to PRISMA guidelines. The results indicate that employing drones in modern warehouse management systems allows for substantial increases in both safety and efficiency. While the use of drones in warehouses is only beginning, the already apparent benefits allow us to anticipate that they will be an integral part of future warehouse operations. Using AI in conjunction with drones adds another layer of safety and efficiency to these operations. The presence of both drones and AI in a warehouse should allow the system to achieve a new level of operational excellence.

However, the study identifies several limitations, including the need for a comprehensive cost-benefit analysis, regulatory challenges, workforce impact, and sustainability considerations. Overall, the integration of AI and drones in warehouse management offers substantial benefits, including enhanced efficiency, improved accuracy, safety enhancements, predictive analytics, cost savings, and sustainability improvements.

1. Introduction

Supply chain operations are changing quickly due to the integration of drone technology and artificial intelligence (AI) in warehouse management. More automated, accurate, and efficient procedures are taking the place of outdated warehouse methods as businesses continue to change due to the use of Industry 4.0 technology. AI-equipped drones are now indispensable tools for streamlining warehouse operations and offer advantages like better inventory control, tighter safety regulations, and cost savings. With an emphasis on the usage of drones in manufacturing environments, this thesis offers a thorough analysis of the industrial uses of AI in warehouse management.

This study intends to investigate how drones, driven by AI, are changing warehouse tasks, from inventory checks to real-time tracking, while addressing the difficulties of integrating these technologies into current systems. It will do this by reviewing the material that has already been published.

Drones play a big part in warehouse management, especially in large-scale businesses where manual inventory management is labor-intensive and prone to mistakes. With their sophisticated sensors and AI-powered navigation algorithms, drones offer a more dependable and expedient option, negating the need for human intervention in dangerous areas. Furthermore, the application of AI improves drone functioning, allowing it to carry out intricate operations like demand forecasting and predictive analytics, which further streamlines warehouse operations. Drones have made warehouse management easier, and since they optimize resources and reduce energy consumption, they also fit in with the growing demand for sustainable practices.

The integration of AI-driven drones presents several problems despite their obvious benefits, such as regulatory concerns, economic consequences, and worker dynamics effects. To solve these problems, this thesis examines the possible advantages and restrictions of drone technology in warehouses and suggests ways to get beyond the barriers that stand in the way of its widespread deployment. This research will offer insights into the future of warehouse management by a thorough analysis of the literature, emphasizing the revolutionary role that AI and drones will play in fostering innovation and efficiency in the supply chain.

CHAPTER 1

1.1WAREHOUSE MANAGEMENT

Warehouse management involves overseeing the daily operations of a warehouse, including receiving, keeping, and distributing products. The aim is to manage the flow of items efficiently, ensuring that inventory levels are correct and that orders are processed quickly.

Warehouse management is an essential link in the supply chain. It plans and analyzes the storage of goods within the infrastructure and controls resources like human capital or IT-operating equipment. Warehouse operations are critical to reducing overall operational costs and the smooth movement of materials/ products in a supply chain, creating one satisfied customer at a time. The industry supplies billions of dollars every day.(Minashkina, 2024)

As seen in Figure 1, Industry 4.0 technologies enhance direct communication between all parties involved in a supply chain, enhancing the smooth operation of the system. This shift necessitates warehouse management in distribution centers to handle inventory and information using advanced technology. Traditional manual labor is no longer sufficient for tasks like order picking, delivery, processing, packaging, and record keeping. Modern warehouse management systems require sophisticated hardware to gather and process information, which Industry 4.0 technologies provide.

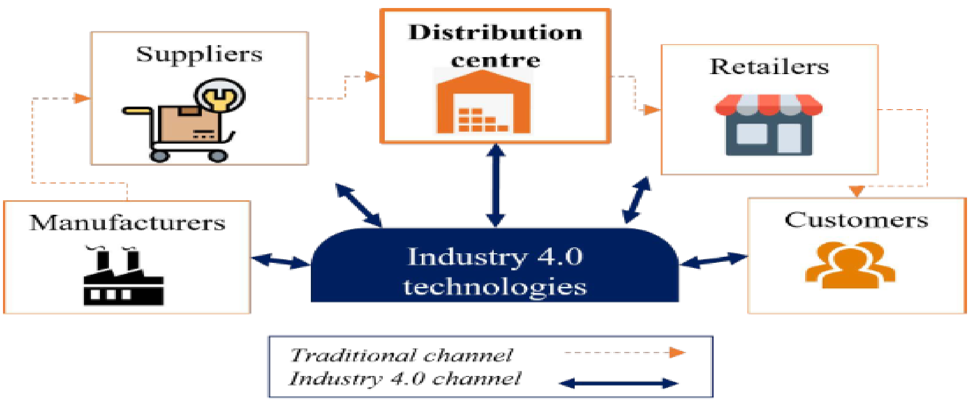

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Figure 1.A supply chain model that applies Industry 4.0 technologies with a distribution center as the core.

https://doi.org/10.3390/logistics7020024

1.1.1 Type of warehouse management

• Inventory Management: Tracking inventory levels, monitoring stock movements, and ensuring proper storage and organization.

• Order Fulfillment: Timely and accurate picking, packing, and shipping of orders.

• Warehouse Layout and Design: Optimizing space utilization and minimizing movement time.

• Warehouse Automation: Using technology like barcode scanners, RFID tags, and automated systems for efficiency. Effective warehouse management improves customer satisfaction, reduces costs, and provides a competitive edge.(Minashkina, 2024)

1.1.2 Warehouse Management System and the Role of WMS in Modern Industry

Over the past several years, warehouse management systems (WMS) have become vital in modern industry. These are advanced software platforms that handle all operational activities within your warehouse - from inventory management and order fulfillment to shipping and logistics. In other words, WMS is designed to provide companies with more accuracy in stock control by integrating real-time data and advanced algorithms which allow faster processing of orders as well enables better utilization of warehouse space and resources.

However, the warehouse management landscape has changed. Drone and artificial intelligence (AI) equipped warehousing are taking over the traditional WMS. This means meeting the demands of modern, fractured supply chains and automating common warehouse tasks for the fastest and most aforementioned error-proof slotting accuracy.

In many warehouse complexes, it is critical to grasp the key differences between traditional warehouse accounting systems and WMS. WMS is more than just an accounting system; it evaluates all of the activities in the queue and delivers a signal to warehouse staff about a task with strong prospects. Furthermore, contemporary WMS readily handles route optimization of storage facilities and equipment, and they construct an operational program for warehouse workers based on the findings of the load analysis.(Minashkina, 2024)

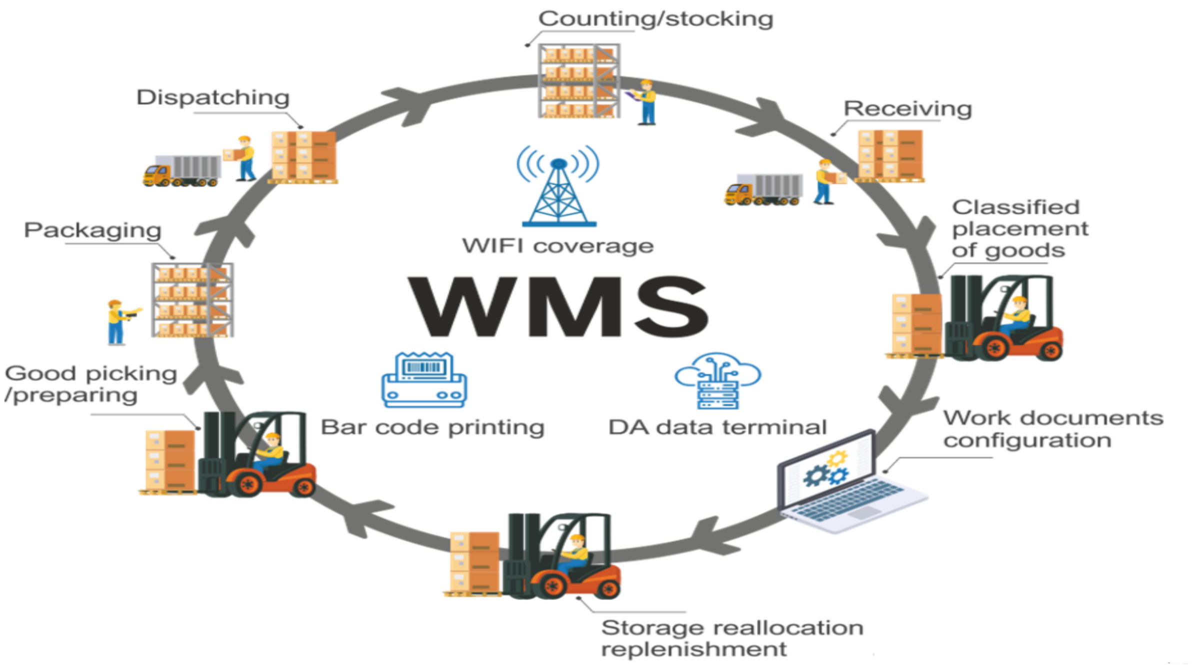


Figure 2. Warehouse management system operation.

1.1.3 The Growing Role of Drones in Warehouse Management

Drones are recognized as key warehouse automation components for larger-scale or more complicated operations. Drones with advanced sensors, cameras, and navigation systems based on artificial intelligence can perform inventory checks automatically in warehouses, monitor stocks, and make routine inspections (Wawrla, Maghazei, & Netland, 2019)

One of logistics' major advantages of logistics is faster and more accurate inventory audits with drones. A traditional manual inventory check is labor intensive, prone to human error, and often requires warehouse shutdowns or slowdowns. Conversely, drones can scan RFID tags or barcodes on in-stock items while using just-in-time and recording information, facilitating the flow of inventory data without disrupting normal operations (Wawrla, Maghazei, & Netland, 2019).

Drones can also assist in limited-reach areas, such as shelves at high levels, which decreases the dependency on forklifts or other equipment and makes warehouses safer. Taking humans off ladders and heavy equipment also helps to prevent common warehouse accidents and injuries by replacing them with drones (Wawrla, Maghazei, & Netland, 2019).

1.1.4 Artificial Intelligence (AI) in Warehouse Optimization

One of the most game-changing advantages that AI has offered in warehouse management is its support for data analysis, providing options to examine huge sets of information and make immediate choices regarding warehouse operations. WMS is becoming more efficient with AI, from predictive analytics to robotic process automation, driving new levels of operational excellence.

Demand Forecasting Another pivotal use of AI in warehouse management is demand forecasting. AI-powered systems can predict future demand almost to date by analyzing historical sales data as well as market trends and other external factors. This empowers warehouse managers to proactively manage inventory levels, ensure stokehold available when necessary, and minimize the cost of holding too much or not enough stock (Blond, 2024).

AI is also deployed to streamline order picking along with routing. Robots or drones driven by AI can be used for quick identification of all the goods in a warehouse and finding out very effectively where which product must go, and from what route. This cuts down on the time and energy that goes into fulfilling orders, whilst also speeding up deliveries to ensure an error-free turnaround for our suppliers.

AI, in addition to providing real-time actionable insights, is also pivotal as far as warehouse automation goes. For instance, human drivers or automated robots can dynamically be assigned tasks by an AI based on proximity to stock items that are needed providing better load balance as well as order priorities. It helps identify the best use of resources within a warehouse, reducing downtime and maximizing throughput (Blond, 2024).

1.1.5 Integrating Drones and AI for Warehouse Efficiency

Drones combined with AI technology are proving to be a potent force multiplier in warehouse management tasks. These technologies span an entire circle of processes – automating activities such as inventory control, picking orders, and inspection of facilities for optimal performance while saving costs. For instance, an AI Drone can also count stock in real-time whilst unloading and reporting any discrepancies to the WMS.

Drones in medicine are those used by drones but more importantly in this activity. A better understanding of the process evolves ’in the use of these new resources within the distribution center, which is an area that many logistics businesses would prefer to glean fewer map drone errors (Wawrla, Maghazei, & Netland, 2019).

These innovations will allow AI and drone technology to replace human effort in warehousing operations which are repetitive and data intensive. We can expect smarter and more efficient warehouses that can meet the rising needs of the supply chains.

1.1.6 Inventory Management in Modern Industry

Leadership Vocab Inventory is one of the processes needed to enhance the achievement of all goals in the process of production and supply operation of business outsourcing including the monitoring of raw materials, work-in-progress inventory, and finished products storage. The management of the inventory facilitates companies to avoid situations of overstocking or understocking to meet customer needs. The targets are to lower expenses, mitigate the possibility of stock outings, and improve the processes of making and delivering orders (Bayas et al., 2023).

In the past, inventory management could be facilitated only through manual systems, a few software packages, and through usage of lots of human resources requiring more time with more errors, inefficiencies, and delays. There are however new technologies that are changing the dynamics of inventory management for various companies including drones and other forms of artificial intelligence. Such revolutions have improved the accuracy of inventory operation in addition to speed and responsiveness within the warehouse without additional labor (Ingka Group. (2024).

1.2 Drones and AI: Essential Components in Optimizing Warehouse Operations

Currently, in most industries, drones and AI are great contributors to streamlining inventory systems in warehouses. Drones connected with RFID scanners or bar codes, for instance, can perform inventory on the stock quickly allowing for fewer man-hours in stock-taking or searching for individual items across large warehouse facilities. These flying objects can access and capture data from tight areas and immediately transfer the data to a warehouse management system to update the inventory log (Cho et al., 2018).

However, there is AI when it comes to smart forecasting, demand planning, or decision. Algorithms with artificial intelligence can compute a lot of data relating to inventories needed at certain times based on the estimates of trends, seasons, and demand from customers. This helps in reaching suitable balances on stocks when filled and on excess implementations, which is needed especially for warehouses. On top of that, an AI approach can also routine the purchase of fill-ins automatically at any point in time when the amount falls below the mark (Blond, 2024).

1.2.1 Together, drones and AI offer several benefits to inventory management:

1. They enable enhanced accuracy by replacing manual counting processes with faster, more reliable inventory data. Humans are prone to error; drones are not, and when paired with AI, the two technologies perform as a single system that offer inventory data with a level of precision not seen before.

2. They create increased efficiency. While humans can only count so many items in a day, drones can do work at a faster pace. AI not only gives the user better access to inventory data but also optimizes the retrieval and storage processes, thus removing whatever operational bottlenecks a warehouse has.

3. They save costs and reduce labor expenses. When one considers that a drone or AI system can complete the same task done by a human but at a lower cost to the business, the bookkeeping becomes clearer. Also, the combination of technologies reduces holding costs (AlRushood et al., 2023).

(https://inventrax.com/blog/impact-of-digital-transformation-on-the-warehouse-2/, n.d.)

Figure 3. Warehouse management aligned with inventory management

1.2.2 Introduction of Drones in Warehouse Management

It has emerged as an indispensable technology in the realm of warehouse management, automating several routine and time-heavy activities like inventory count/inventory control/real-time monitoring/data collection. The era of drones is rapidly settling into conventional processes across business verticals especially where there are some common elements to repeat advertising (retail). In the old days, inventory counts were performed in a labor-intensive manner where employees walked through wide warehouse aisles scanning barcodes or visually accounting for stock levels. It was time-consuming, and on top of that, more prone to human error (Wawrla, Maghazei, & Netland, 2019).

Drones, on the other hand, provide an automated way to accomplish it all much faster. Drones with RFID scanners, barcodes, or even good imaging sensors can fly through spaces of vast warehouses and scan and count stocks in a fraction it would take for an entire human workforce to do. This gives them considerable advantage in scanning inventory checks as an automated process and vastly improves the speed at which it is done. If anything, drones can complete inventory audits every day without disrupting warehouse activities making it possible to keep track of current inventories at any given time (Bayas et al., 2023; Wahab et al., 2023).

Besides inventory management, drones can also be used for real-time surveillance and monitoring. This allows them to record bird-eye images of warehouse layouts and operations and locate bottlenecks or safety hazards. They can analyze this data to optimize warehouse design, pinpoint inefficient processes, and guarantee safety compliance

1.2.3 AI in Warehouse Management and Its Synergy with Drones

Artificial intelligence (AI) complements the physical functions facilitated by drones such as data collection, and enables smart decision-making or automation based on the masses of collected data. By capturing and analyzing in real-time, AI makes drones much smarter and delivers actionable insights into the hands of warehouse managers (Choi et al., 2022; Wawrla et al., 2019).

Take, for example, drones that are integrated with AI-powered software go one step further than simple inventory counting. predicting demand ebbs and trends in stock movements. (Dinh, 2020). With the help of AI algorithms, the warehouse utilizes historical data to predict your future needs and maintain desired levels. This way, you ensure to minimize stockout and oversupply leading to overall cost effectiveness.

Moreover, AI enhances the navigational and decision-making capabilities of drones. Drones can automatically plan the optimal flight paths for scanning inventory and avoiding blockages in warehouses with machine learning algorithms. This autonomy level reduces human involvement and guarantees that inventory activities are performed at maximum precision & speed (Charoenkwan & Wudhikarn, 2023).

AI also has an essential rule in automating warehouse tasks such as order processing and stock replenishment. An AI-powered WMS (Warehouse Management System) can automatically call a drone to go and find and calculate an item for dispatch, when replenishment is required or even trigger a reorder of the inventory of an item should that stock level fall below as set threshold. A logical consequence of this digital twin technology is the almost seamless integration between physical operations (handled by drones) and strategic decision-making processes (modeling AI), optimizing or predicting an efficient warehousing process (AlRushood et al., 2023).

1.3 Digital Technology and Automation in Warehouses

The warehousing sector has seen huge changes in recent years, and a lot of it came from technologies that were made possible by automation (Dinh, 2020). With greater demands for time-sensitive delivery, more advanced inventory management, and faster order fulfillment blossoming worldwide — manufacturers have leaned on both digital as well physical automation solutions to tackle these challenges in their warehousing operations (Marchuk & Harmash, 2020).

Digital Automation is the productivity system by which software solutions are used and put into service to optimize common warehouse processes. An example is the Warehouse Management System (WMS) which utilizes AI algorithms to automate decision-making tasks like inventory tracking, order fulfillment, and space utilization. WMS can easily integrate with other solutions like Enterprise Resource Planning (ERP) and Advanced Planning and Scheduling to create a foolproof digital ecosystem that allows online tracking as well as decision-making (Marchuk & Harmash, 2020). On the other hand, Physical Automation refers to automated devices and machinery implemented in storage houses (AlRushood et al., 2023).

This includes technologies such as Autonomous Guided Vehicles (AGVs), robotics, and drones which are finding their way into the warehouse. They are transforming how products are stored, picked, and transported in warehouses. For example, drones are key for real-time inventory audits and save a vast amount of time when compared to traditional manual inventory checks.

(Dinh, 2020). Warehouses are getting automated and intelligent thanks to AI and drone technology which has the capability of observing everything within a ware space and gives us more knowledge on optimizing every process such as inventory management, picking & packing with little interference. The combination of digital and physical automation allows warehouses to operate more efficiently, accurately, and quickly — ultimately lowering costs and improving supply chain performance overall (Charoenkwan & Wudhikarn, 2023).

1.4 Research Gap

Even while the field of study on artificial intelligence (AI) in logistics and warehouse automation is expanding, there is still a dearth of information in the literature about the application of drones in manufacturing warehouses, particularly when combined with AI. While a large body of recent research has focused on the broad uses of AI in supply chain and logistics optimization, fewer studies have examined the possibilities of drones and AI together for inventory management and other warehouse operations. This offers a special chance for more research. More research is needed in a few important areas, especially about the following queries.

1.5 Research Questions:

Many studies focus on AI in logistics or warehouse automation, but fewer address the combined use of drones with AI for inventory management and other tasks.

1. What is the cost-benefit implications of integrating drone technology into warehouse management systems?

2. How can drones aid real-time tracking and monitoring for improved supply chain - transparency?

3. What is the impact of AI-driven drones on workforce dynamics and employment within warehouse operations?

4. What are the regulatory challenges associated with the use of drones in warehousing, and how can businesses navigate them?

5. How do drones contribute to sustainability efforts in warehouse management through optimized routing and reduced energy consumption?

Summary

I. 1. Cost-Benefit Implications for Integrating Drone Technology into WMS:

• While drones improve accuracy and efficiency, particularly in inventory management, there is a lack of research on the costs associated with their use. Important considerations are the upfront cost, continuing upkeep, possible labor cost savings, inventory accuracy, and error reduction.

II. 2. Drones and Real-Time Tracking for Improved Supply Chain Transparency:

Drones are an effective tool for tracking and monitoring items in a warehouse in real-time. This provides real-time inventory data and quick stock level updates, which improves supply chain transparency. Although this potential is known, there isn't much research on how AI-powered drones might particularly enhance real-time visibility and transparency throughout whole supply chains, including how this can cut lead times and avoid stockouts.

III. 3. Impact of AI-Driven Drones on Workforce Dynamics and Employment:

• There are significant concerns over the impact of AI-driven drone integration on the workforce when it comes to warehouses. Will there be job displacement or chances for warehouse employees to upskill because of the automation of jobs that were previously performed by humans, such as inventory counting and stock retrieval?

IV. 4. Regulatory Challenges of Using Drones in Warehousing:

• Regulations about privacy, safety, and airspace management are challenged by the usage of drones in both indoor and outdoor settings. Rules about drone activities can be complicated, especially in warehouses next to manufacturing sites. It is not well covered in the literature now in publication how companies can get over regulatory obstacles, such as adhering to international, national, and municipal regulations regarding the use of drones.

V. 5. Drones and Sustainability in Warehouse Management: (Atieh et al. (2016))

The potential use of drones in sustainable warehouse management initiatives is yet a topic of understudied research. By streamlining operations, drones can minimize the carbon footprint of the warehouse, optimize routing, and eliminate the need for energy-intensive machinery. The advantages of drones for sustainability, like lower energy use, less waste, and more effective resource use in warehouse settings, have, however, received little attention.

CHAPTER 2

2. Lecture Review

2.1 DIGITAL TECHNOLOGY AND AUTOMATION APPLIED WAREHOUSE

“Statistics show that warehouse management costs account for most of a company’s overall logistics costs”. It has also been indicated that logistical costs in inefficient countries can be as high as 25% of the national gross domestic product (GDP), negatively affecting the whole manufacturing value chain. Therefore, adopting efficient and appropriate measures to achieve effective management and control of materials is a key means to adjust the supply and demand of storage materials and reduce operating costs (McKinsey & Company. (2020).

Also, For the most part, labor expenses cover the operational budgets of warehouses. It is economical and has a good return on investment to replace manpower in warehouses with automation. Robots don't need insurance, benefits, or vacation days, and they are exempt from labor regulations (Weever Apps. (2021) Another frequent problem in warehousing is a labor shortage during the busiest shopping season. Staff turnover is the main cause of fulfillment problems. When it comes to managing unpredictable demand, human warehouses can hardly compete with an automated warehouse's ability to handle order surges during busy holiday seasons.

Digital applicable candidate Industry 4.0 technologies are revolutionizing warehouse operations, enhancing efficiency, reducing errors, and fostering a new level of customer visibility (LinkedIn. (2021).

Modern warehouses prioritize value-added services, order customization, and rapid flow-through processes, utilizing just-in-time inventory principles to stage products efficiently.

- 8 Questions to Decide If It’s Time to Automate Your Warehouse

Answer these questions before committing to warehouse automation projects:

1. Are your customer orders delayed due to a limited workforce?
2. Are your existing warehouse processes and procedures labor-intensive?
3. Is your order fulfillment capacity declining?
4. Are your inventory counts inaccurate?
5. Are you still using legacy warehouse management software or manual inventory tools?

6. Is customer satisfaction data indicating problems in the supply chain?
7. Do you have to increase/decrease your workforce to meet fluctuating demand?
8. Do you have buy-in from key stakeholders?

2.1.1 WMS improves the integration of digital automation

A Warehouse Management System (WMS) is a software platform designed to manage and optimize warehouse operations, such as receiving, storing, picking, packing, and shipping materials. Over the past few years, WMS technology has evolved to enhance warehouse management by digitizing and automating processes (Miller & Lee, 2020).

In addition to basic tasks like order fulfillment and inventory control, WMS can integrate with other systems such as Advanced Planning and Scheduling (APS) and Enterprise Resource Planning (ERP) to provide comprehensive warehousing solutions (Calsoft Systems, 2021). Traditional manual operations are now being replaced by cutting-edge tools like the Internet of Things (IoT) and RFID technology, which enable real-time tracking, reduce human error, and boost overall warehouse efficiency (AR Racking, 2021). IoT-based WMS designs enhance real-time management, improve productivity, and prevent inventory shortages and counterfeiting (SAP, 2021).

Enhanced actions: By digitizing, simplifying, and automating tasks, such as receiving, storing, picking, packing, and shipping, a WMS enhances warehouse actions

Lower operating expenses: A WMS may save overtime and boost employee spirit in the warehouse by automating manual, repetitive tasks (Clarus WMS, 2021).

Improved decision-making: Businesses may get a more complete view of their actions and financial health by integrating a WMS with an enterprise resource planning (ERP) system or other finance tools (Calsoft Systems, 2021).

Advanced technologies, such as visualization techniques like alternate reality, automate warehouse performance and integrate activities into the supply chain, enabling intuitive management of commodity stocks and supplies. (Miller & Lee, 2020).Also, some digital technologies such as the Internet of Things, robotics, drones, artificial intelligence, and others, which have been applied in a warehouse subsystem of the logistics system, have become widespread all over the world (Clarus WMS, 2021).

2.2 Drones in Manufacturing Warehouses:

- **Inventory Control**: Effective inventory management is crucial for businesses to Balance meeting customer demand and avoiding unnecessary carrying costs (Investopedia, 2021).
- **Inventory Tracking**: Implementing systems and technologies to monitor the movement and status of inventory items throughout the supply chain. (SelectHub, 2021).
- **Stock Replenishment**
- Stock Maintenance: This involves managing inventory levels and ensuring that inventory is available when needed (SafetyCulture, 2021).
- Ordering and Reordering: Determining when to order a new inventory and in what quantities to maintain optimal stock levels while minimizing holding costs (Atech Logistics, 2021).
- **Surveillance**
- **Surveillance**: Drones can enhance warehouse security through aerial surveillance, providing a comprehensive view of the facility (SelectHub, 2021).
- **Safety**
- **Safety**: Drones play a role in improving workplace safety by minimizing risk, drones contribute to a safer working environment (Garcia et al., 2021).

2.2.1 Inventory Management

Inventory refers to goods held in a warehouse, including raw materials, components, WIP (work in progress), and finished products. It can also extend to data and customers in service industries (Atech Logistics, 2021).

insurance. Reducing excess inventory is crucial to avoid unnecessary expenses and risks.

- **Purpose of Inventory**: Inventories act as a buffer between production and demand, ensuring timely delivery of goods. For example, supermarkets keep stock on shelves to meet immediate consumer demand, while Amazon uses fewer distribution centers to achieve rapid delivery despite longer customer wait times (SafetyCulture, 2021).

- **Role of Inventory Management**: It involves organizing and storing goods effectively in warehouses. Advanced technologies, such as IoT and RFID, are used to streamline operations, cut labor costs, and minimize errors (SelectHub, 2021).

2.2.2 Drones and AI in Inventory Management

- **Drones and AI Integration**: These cutting-edge strategies seek to improve customer happiness, cut expenses, and optimize warehouse operations (Kaur & Mehta, 2021).
- **Real-Time Data**: RFID technology may save labor expenses, increase productivity, and lessen data loss (SelectHub, 2021).

2.2.3 Warehouse Layout Design

- When constructing a warehouse, there are several things to consider, such as information technology, equipment, capacity, flow, accessibility, cost and budget, and safety concerns. Table 1.1 is shown below: (NetSuite. (2023).

Factors	Description
Cost/budget	The location, size, capacity, and layout of a warehouse should be evaluated based on the business budget, requirements, and future projection of your business growth.
Capacity utilization	Effective capacity utilization in the warehouse is crucial for operational efficiency as it can help reduce travel distance, pickup time, and inventory visibility, etc. A good layout design should consider how capacity can be utilized most effectively within a warehouse.
Flow	A good layout design should also maintain a smooth flow of goods, vehicles, personnel within a warehouse, avoiding inefficient routes, bottlenecks, and disruptions, etc.
Accessibility	A good layout design should ensure easy accessibility to all areas within a warehouse so that goods can be conveniently located and picked up without

	having to move other products.
Equipment	Choosing the right types of equipment for scanning, recording, sorting, lifting, conveying, storing, packing can influence productivity and efficiency of warehousing as well as the layout design.
IT	Large warehouses are often enabled with modern technologies. Different IT systems for sensing, tracking, recording, communication, etc. including warehouse management systems, can also impact a warehouse's layout design, and hence the process efficiency and productivity of a warehouse.
Safety	A good layout design should also ensure the safety of employees working in a warehouse by strictly following guidelines and industry standards.

Table 1. Important factors to consider for warehouse layout design

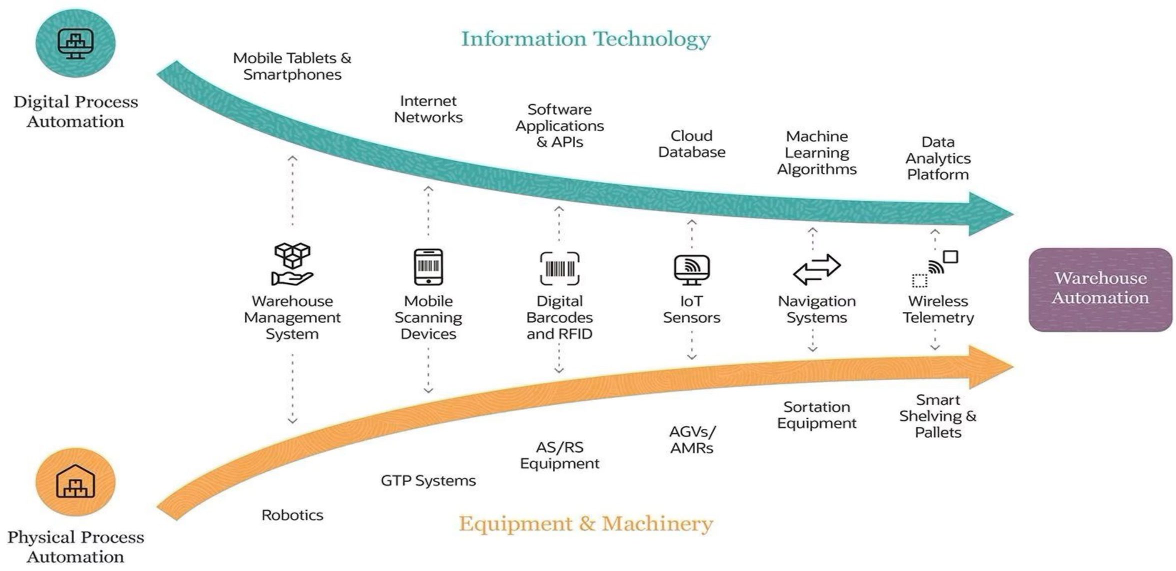
(https://doi.org/10.1007/978-3-030-92224-5_7#DOI)

2.3 Warehouse Automation

Warehouse automation is the process of moving merchandise into, within, and out of warehouses with minimal human intervention. It reduces labor-intensive tasks and manual data input and processing. It doesn't involve physical or robotic automation but often involves software replacing human activities. Automation can start with a warehouse management system (WMS), data collection, and inventory control. Although it has significant upfront costs, benefits include improved operations and reduced human error. (SAP, n.d.).

2.3.1 What Is Digital Automation?

Digital automation reduces manual workflows in warehouses using AIDC technology like mobile barcoding. It integrates with ERP systems, enhances security, improves data management efficiency, reduces operational risks, and improves safety. AIDC technology enhances work experience, customer service, and operational costs. However, it requires significant upfront investment, including hardware, software, support contracts, time, and resources. Additionally, digital automation increases the risk of data loss, corruption, and cybersecurity threats (Lowry Solutions, 2021).



(https://www.netsuite.com/portal/resource/articles/inventory-management/warehouse-automation.shtml)

Figure 4.Warehouse Automation

2.3.2 What Is Physical Automation in the Warehouse?

Physical automation improves workflow efficiency and increases warehouse capacity, reliability, and performance. It requires advanced planning and organization and is best suited for large-volume warehouses and distribution centers. Automated warehouse systems use software and technology like robotics and sensors, integrating with existing tools like inventory management software. Warehouse automation ensures business-critical operations meet customer demand by automating manual processes, data capture, inventory control, and data analysis (Jones & Green, 2022; (NetSuite, 2023).

3.3 How Does Warehouse Automation Work?

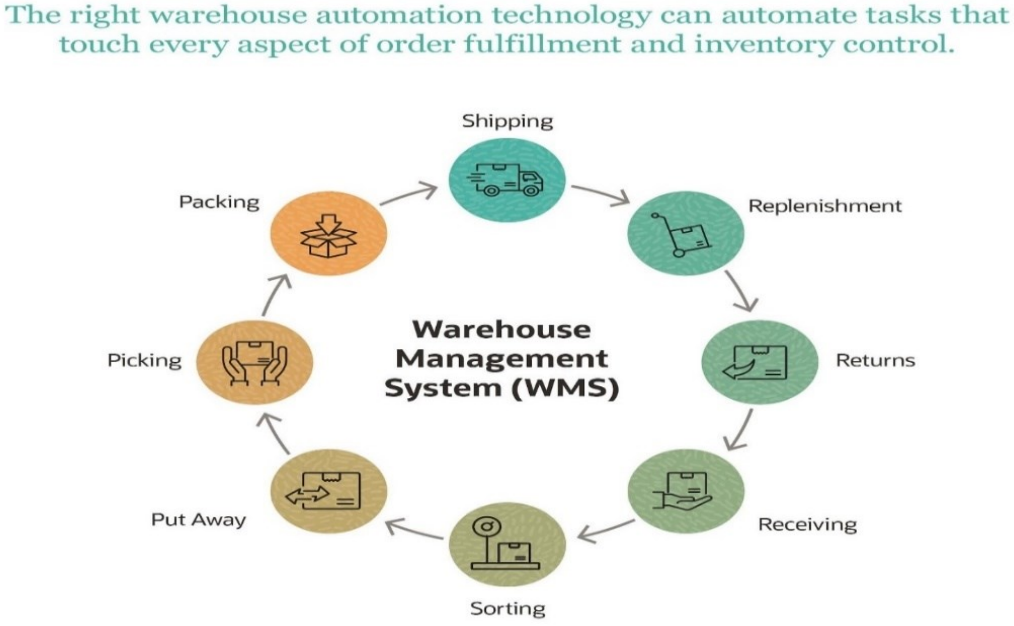
Warehouse automation uses software and technology like robotics and sensors to automate tasks, meet customer demands, and manage business-critical operations. It starts with a warehouse management system (WMS) that automates manual processes, data capture, and inventory control, and supports data analysis, integrating with other solutions (Smith & Clark, 2023).

2.3.4 The right warehouse automation technology

Warehouse automation technology can streamline tasks in order fulfillment and inventory control. It can collect data from mobile devices in the warehouse reception area, allowing for efficient data capture, processing, and storage. Return processing operations can be automated using conveyors and sorting devices, allowing merchandise to be restored or stored in specific areas. Put-away processes can be automated to improve accuracy and efficiency, and cross-docking can be facilitated.

Automated picking can be done more efficiently using GTP systems and autonomous mobility robots. Sorting and consolidation can be automated to handle small or fragile inventory individually, enhancing inventory accuracy and quality control. Automated reordering is made possible through cycle counting and automated inventory tracking, reducing the costs of overstocking and loss from theft and spoiling (NetSuite, 2023).

Packaging is crucial for order fulfillment, and algorithms are used by automated packing and centonization systems to choose the optimal shipment package type based on product characteristics, size, and material prices. Automated shipping systems use conveyors, scales, dimension sensors, printers, and software to identify available carriers, calculate shipping costs, and mark items for delivery. Overall, warehouse automation technology can significantly improve efficiency and reduce costs in order fulfillment and inventory control.



https://www.netsuite.com/portal/resource/articles/inventory-management/warehouse-automation.shtml *Figure 5. Warehouse Automation technology*

2.3.5 Warehouse automation categories

Warehouse automation categories include:

• **Basic Warehouse Automation:** Simple technology aids manual tasks like transporting items. (Tubis & Rohman, 2023).

• **Warehouse System Automation**: Utilizes robots, software, machine learning, and data analytics to automate processes (Soori et al., 2024).

• **Mechanized Warehouse Automation:** Uses robotic systems and equipment to assist in warehouse tasks. (Pramanik et al., 2020).

• **Advanced Warehouse Automation:** Combines automated systems and mechanized warehouse robotics to replace labor-intensive human activities.

• **Online tracking site:** Provides location information for robotic forklifts guided by AI, cameras, and sensors (Alherimi et al., 2024).

2.3.6 Warehouse automation technology includes:

• **Goods-to-Person (GTP):** Utilizes conveyors, carousels, and vertical lift systems to increase productivity and reduce traffic (Tubis & Rohman, 2023).

• **Pick-to-Light and Put-to-Light Systems:** Guide warehouse pickers using mobile barcode scanning and digital LED displays.

• **Voice Picking and Tasking: Uses mobile headsets and speech recognition software to** generate optimal pick pathways. Allow pickers to focus on work with greater efficiency and safety, eliminating the need for portable electronics (Pramanik et al., 2020).

2.3.7 Key Warehouse Automation Trends

Here's a list of the digital and physical warehouse automation and robotics that are applicable candidate Industry 4.0 technologies that trends empowering the modern warehouse:

1. **Decision Support System (DSS) Tools**
2. **Radio Frequency Identification (RFID) Technology**
3. **Augmented Reality (AR)**
4. **Robotics**
5. **Cobots**
6. **Warehouse Cleaning**
7. **Autonomous Vehicles** (AGV)
8. **Autonomous Mobile Robots**
9. **Internet of Things (IoT)**

10. **ERP Integrations**

11. Warehouse Drones

Robotics has gained popularity in warehouses, with the use of drone fleets for shipping and delivery fulfillment becoming increasingly popular (Attaran, 2020). Advanced algorithms and cloud-based warehouse management systems (WMS) can help manage inventory and automate processes like cycle counting (Soori et al., 2024). Drones are becoming more popular due to advancements in legislation, technology, software, and reduced costs. Hardware improvements have improved stability and battery life, making software-led, hardware-independent solutions popular since 2018 (Pramanik et al., 2020). Drones can be used for tasks beyond shipping and delivery, such as cycle counting, aerial inventory scans, and inspection (Tubis & Rohman, 2023). The first autonomous drones were used by third-party logistics firms and air freight facilities. However, battery life limitations and bandwidth issues pose major obstacles to their adoption (Pramanik et al., 2020).

By 2028, the worldwide drone market for logistics and transportation is projected to reach $12,180 million, growing at a 10.8% CAGR. This market affects infrastructure, software, shipping, and warehousing. The shipping and warehousing sectors are predicted to increase at a substantial rate. North America is expected to develop at the fastest rate throughout this time due to businesses like UPS, DHL, and Amazon (Attaran, 2020).

2.4 Warehouse Technology Trends

Blockchain Technology

Blockchain technology is a secure automated network that uses encryption to create data transfers on a shared digital ledger. It enhances inventory management and warehouse operations by providing superior data authentication, validation, and transparency. It improves safety by creating tamper-proof records, making it a safer option for centralized warehouse management. Walmart and IBM collaborated to use blockchain technology to increase safety and predict food scares (OsCM, 2020).

Cloud-Based software

Cloud computing technology allows institutions to access stored data and resources from anywhere using smart devices. It improves warehouse operations, streamlines workflow, and integrates with transport management systems (OsCM, 2020).

Cloud-based warehouse management solutions are becoming more common among logistics organizations due to their lack of internal IT support or infrastructure.

Cloud-based solutions offer increased automation potential, ease of integration with other systems, increased connectivity with IoT-enabled devices, accurate inventory control, rapid implementation, centralized data accessibility, and unlimited computing power (OsCM, 2020).

Packing

Robots and automation in packaging have revolutionized warehouse operations.

Trends include the 3D bin packing method, modules for documentation insertion, and robotic packaging. (OsCM, 2020).

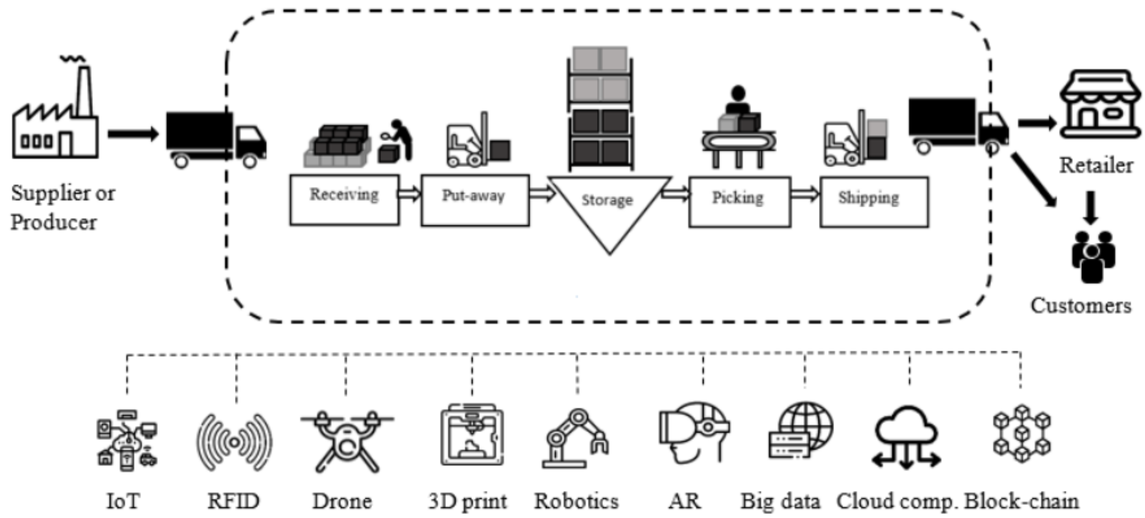


Figure 6. Warehouse operations and related digital-era technologies

http://doi.org/10.31387/oscm0490340

❖ Real-world Examples of Warehouse Automation

The popularity and growth of e-commerce has increased the demand for warehouse automation. Here are some examples of how it works across various industries:

- **Amazon** uses automated barcode scanning and labels to optimize warehouse operations, allowing for unique barcodes on incoming products and shelves.
- **Fast Shipping** The “Amazon effect” of one- or two-day shipping has created intense demand for rapid online shipments regardless of who sells the product. Same-day shipping will continue to drive warehouse automation that speeds up order fulfillment tasks like picking and improves the accuracy and cost-effectiveness of automated packaging and shipping procedures
- **Nike** implemented a GTP picking system in its distribution center in Japan, using autonomous robots to carry products and packages directly to warehouse workers for order fulfillment.
- **IKEA** operates highly automated warehouse facilities worldwide, featuring AS/RS inventory automation systems and equipment, such as 100-foot-tall trilateral stacker cranes and conveyor rack systems capable of automatically transferring 600 pallets an hour to dispatch areas.
- **Back-office automation** can be optimized using WMS platforms with digital process automation features. I Automation, a distributor of machine control solutions and services to OEM machine builders, implemented NetSuite's Inventory Management, CRM, and Manufacturing Execution System to enhance back-office sales and customer support functions with automated barcoding, case management, and issue tracking solutions. (Cleveroad, n.d.) (Mordor Intelligence, n.d.).

2.5 Connecting Risk Management Using Modern Warehouse Technology

Modern warehouse technology has significantly improved the reliability of operations by enhancing efficiency and work quality. It leads to more efficient use of warehouse space, reduced energy and labor consumption, enhanced control over warehousing processes, and decreased manual handling activities. This results in reduced operational costs and fewer workplace accidents. Two primary categories of modern warehouse technology are storage and handling equipment, such as Automated Guided Vehicles (AGV) and Automated Storage and Retrieval Systems (AS/RS), and modern order-picking solutions, such as Warehouse

Management Systems (WMS), RFID, Voice Picking Technology (VPT), and light-picking technology(LPT).

Risk management and error reporting culture significantly impact the implementation and use of modern warehouse technology. Mistrust and lack of knowledge hinder the adoption of modern solutions. Establishing high-risk management can overcome potential issues and enable warehouse operators to participate effectively in the design, creation, management, maintenance, and control of modern technological solutions. However, there is a research gap in the role of risk management in modern warehouse technology adoption (Muha et al., 2020).

2.5.1 Advantages of automation in warehouse business processes

The benefits of automation of warehouse business process and implementing Industry 4.0 technologies and decision support systems in warehouse management are (1) improved process efficiency, (2) the availability of real-time data, (3) added competitive advantage, (4) integrating activities digitally, (5) enhanced flexibility, (6) improved decision making, (7) reduced operational costs, (8) better risk management and (9) enhanced security,(10) Improved Inventory Management, (11) Sustainability through Smart Energy Management, (12) customer satisfaction Pareto analysis indicates that the first four constitute the most important benefits.

2.5.2 Disadvantages of automation in warehouse business processes

Disadvantages inherent to both the automation of warehouse business processes and the implementation of Industry 4.0 technologies.

(1) Reduced Human Workforce, (2) Initial High Costs, (3) Maintenance and Upkeep, (4) Lack of Flexibility, (5) Cybersecurity risks) Data Loss of Human Expertise, and Disadvantages of Implementing Industry 4.0 Technologies: (1)Data Privacy and Control Issues, (2)High complexity and Need for Customization, (3)Reliance on Unproven Technology, (4)Integration Challenges, (5)Requires Continuous Learning and Adaptation, (6)Scalability Bottlenecks,

(Tikwayo & Mathaba, 2023),(Jarašūnienė et al., 2023)

CHAPTER 3

3. Research Methodology

3.1 Systematic literature review

A systematic literature review (SLR) is a methodical and comprehensive approach to collecting, evaluating, and synthesizing all relevant research on a specific topic or question. The goal of this procedure is to reduce prejudice and offer a solid basis for judgments. The systematic literature review (SLR) methodology comprises multiple essential steps, such as formulating a precise research question, creating a protocol for the review, searching the literature extensively, choosing studies according to predetermined standards, evaluating the caliber of the included studies, and summarizing the results (Tikwayo & Mathaba, 2023).

SLRs have been utilized in the context of small and medium-sized businesses (SMEs) to investigate the effects of leadership on growth and technology adoption in the face of changing technical environments. Similarly, SLRs are an essential tool for compiling and evaluating current knowledge in more specific fields like the definition of treatment burden, the use of blockchain for mobility in smart cities, and the conception of the Metaverse. (Tubis & Rohman, 2023), (Wahab et al., 2023).

A systematic literature review (SLR) on adopting drones in warehouse management reveals key factors influencing their utilization. Factors such as hardware (payloads, battery power, sensors) and software (scheduling, path planning, localization, navigation algorithms) play crucial roles in drone adoption for warehouse operations. Drones are increasingly being used in warehouse settings for inventory management, stock inspection, and visual feedback, offering efficient alternatives to manual processes (Malang et al., 2023). The use of drones in warehouses is aimed at streamlining inventory management processes, enhancing monitoring and inspection activities, and supporting green warehousing practices. Additionally, the precise positioning of drones in warehouses using virtual fiducial markers has been explored to improve item counting accuracy and operational efficiency (Rejeb et al., 2021).

This section outlines the systematic review method employed to operationalize this study to answer research questions. It outlines the stages within the systematic review process. The researcher's philosophical stance and positionality are discussed within the description of the stages involved. Finally, the types of syntheses conducted are rationalized.

3.2 The Systematic Review Process /PRISMA

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) process is a widely used guideline for conducting and reporting systematic reviews and meta-analyses.

The PRISMA statement has been widely used in scientific research since its initial publication in 2009(Page et al., 2021). In 2015, an updated version of the PRISMA statement was published, which included new items related to the reporting of systematic reviews and meta-analyses. Since then, the PRISMA statement has continued to evolve, with the latest version being published in 2020. Page et al. (2021) note that the use of PRISMA can improve the transparency, completeness, and accuracy of reporting in systematic reviews, and can facilitate the reproducibility and critical appraisal of the review. They recommend that authors should use the latest version of the PRISMA statement, which was updated in 2020, and should provide a completed PRISMA checklist and flow diagram as part of their manuscript submission. The PRISMA process involves the following stages: (Page et al., 2021).

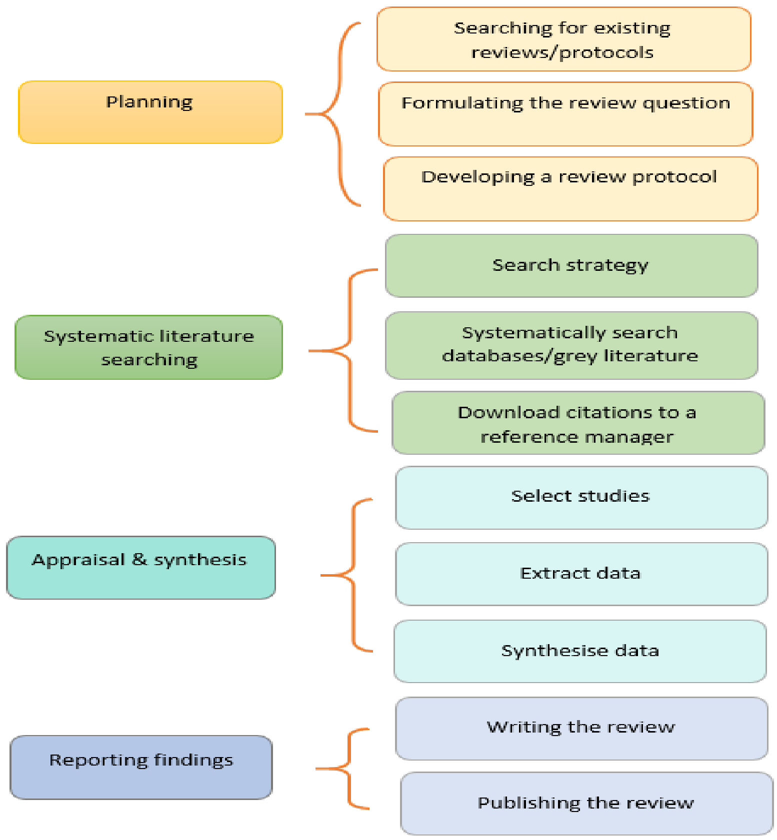


*Figure 7. Process of systematic literature review.*https://sp.library.miami.edu/subjects/systematicreview#tab-6

By following this PRISMA methodology researchers can ensure that their systematic review or meta-analysis is rigorously transparent and reproducible.

1. Planning:

This stage involves preparing and structuring the literature review. It includes:
Looking for previous reviews or protocols: It's crucial to see whether any reviews that are comparable to the one you're starting have been done before beginning a new one. Creating the review query: Establish a precise and targeted research topic to direct the review. Formulating a process for review: Describe the approach that will be taken in the review process (PRISMA, 2009).

2. Systematic Literature Searching:

This stage is about searching for relevant studies systematically. It includes:
Create a plan for the literature search that includes databases and keyword research. Methodically look through databases and gray literature: To obtain literature from databases and other sources, such as conference papers or reports, use the search approach. Get citations to be stored in a reference manager: Sort the gathered references with a citation management program (Zotero, EndNote, etc.). (PRISMA, 2009).

3. Appraisal & Synthesis:

This stage is focused on selecting and evaluating the studies. It includes:
A few studies Using predetermined criteria, select the most pertinent studies. Retrieve information: Collect the relevant information (methods, outcomes, etc.) from the chosen studies. Combine data: To create an overview and respond to the research question, compile the retrieved data. (PRISMA, 2009).

4. Reporting Findings:

In this final stage, the findings from the review are reported. It includes:
Composing the evaluation: Write a review report that explains the findings and how the study The question is related to them. Releasing the evaluation Send the review to be published in a scholarly publication or make it available to the public. (Moher et al., 2009).

The review was conducted in an ongoing exchange with the supervising professor.

3.2.1 Inclusion and exclusion criteria

Inclusion criteria

Criteria	**Motivation**
only scientific articles or journal article should hence dissertations, books, book chapters, and book reviews were excluded	Since this subject is a new technology, This research is only limited to scientific publications to set and maintain a consistent high-quality quality globally accepted standard from which the research will be conducted.
Research on Warehouse Management Methodology/-ies by drones	This is the main area in which the research is focused.
Written in **English**	This research only focuses on academic. publications written in English or officially translated to the English language.
Publication date from **2019 to 2022**	This research will draw from the last decade of publications to draw the latest best practices

Table 2.Inclusion criteria

Exclusion criteria

Criteria	**Motivation**
Non-academic publications	dissertations, books, book chapters, and book reviews were excluded
Publications in languages other than English	The research study language is English
Publication date prior to 2019	
Conference Reviews	
Duplicates	

Table 3-Exclusion Criteria

3.2.2 Data Collection/Prisma

According to the PRISMA statement, the data collection process for the PRISMA flow diagram should include the following four steps: (Page et al., 2021)

- **Identification**: The initial step involves identifying eligible studies through electronic databases, hand-searching relevant journals, and contacting experts in the field.
- **Screening**: The next step involves screening the identified studies for eligibility, reviewing titles and abstracts, and obtaining full-text articles for those that meet the criteria.
- **Eligibility**: The process may involve reviewing study titles and abstracts and obtaining full-text articles for those that meet the eligibility criteria.
- **Included Studies:** The final step is to compile a list of the studies that were included in the review. This list should include information about the study design, population,

intervention, comparison, and outcome (PICO) elements, as well as any relevant data that were extracted from the studies.

This thesis is based on extensive literature research using the following databases:

- SCOPUS, SCIENCE DIRECT, and RESEARCHGATE. Subsequently, to identify additional

studies, relevant citations within the selected articles were traced and the source it originated from was included in the corps of literature used for this review.

The research was mostly conducted in March 2024, but additional literature collection was carried out in April 2024. More specifically the research on Scopus was conducted on March 15th, while those on ScienceDirect, and Web of Science were conducted on March 20th. The research on Emerald was conducted on March 25th. Additional literature was scanned through tracing of citations during the week of March 27th.

Research Questions

1. What are the cost-benefit implications of integrating drone technology into existing warehouse management systems?

2. How can drones aid in real-time tracking and monitoring for improved supply chain transparency?

3. What is the impact of AI-driven drones on workforce dynamics and employment within warehouse operations?

4. What are the regulatory challenges associated with the use of drones in warehousing, and how can businesses navigate them?

5. How do drones contribute to sustainability efforts in warehouse management through optimized routing and reduced energy consumption?

Figure 8.Visual overview of research design and methodology

3.2.3 Search Strategy / Keywords

Conducting a review phase starts with identifying research studies and this identification starts with the definition of search industrial applications of AI in warehouse management with a focus on using drones in manufacturing.

The keywords used for the trial run were 'warehouse management', 'drones', and 'manufacturing'. After scanning the literature for keywords, there was a list of synonyms and related terms for each key concept. For example:

Categories	Keywords
AI	**Machine Learning, Neural Networks, Deep Learning**
Warehouse Management	**Logistics, Supply Chain Management**
Drones	**Unmanned Aerial Vehicles (UAVs), Aerial Robots**
Manufacturing	**Production, Industrial Processes**
Develop Search Queries	**Combine the key concepts with their synonyms using Boolean**

Table 4. Keywords for the review process

operators (AND, OR, NOT) to create search terms and queries.

Search terms.
("Artificial Intelligence" OR "Machine Learning" OR "Neural Networks" OR "Deep Learning") AND ("Warehouse Management" OR Logistics OR "Supply Chain Management") AND (Drones OR "Unmanned Aerial Vehicles" OR "Aerial Robots") AND (Manufacturing OR Production OR "Industrial Processes")

Table 5.Search terms

Search query.
TITLE-ABS-KEY ("warehouse" OR "warehouse manage*" OR "warehouse inventory") AND ("drone*" OR "Unmanned Aerial Vehicles" OR "UAVs") AND ("manufacture*" OR "operation" OR "Autonomous*") AND (LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO Autonomous (SUBJAREA , "MATE") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "CHEM") OR LIMIT-TO (SUBJAREA , "CENG") OR LIMIT-TO (SUBJAREA , "ECON") OR LIMIT-TO (SUBJAREA , "EART") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "ARTS") OR LIMIT-TO (SUBJAREA , "AGRI") OR LIMIT-TO (SUBJAREA , "NEUR") OR LIMIT-TO (SUBJAREA , "PSYC")) – 2019-2024

. search query 6 Table

It has been used to take advantage of advanced search features offered by databases to refine the search results, such as date filters, publication types, and language options.
Scopus was subjected to restrictive criteria because, when the same query was used for the other databases, it produced an excessive number of results (2.150) that were not relevant to the issue.

Hence, the search area was restricted to the title, the abstract, or the keywords of the article, resulting in 999 results.

The search on ScienceDirect followed a different procedure since the author doesn't possess an account that would allow for advanced research. Hence the initial three terms were used ("drones" OR "drone" OR "Unmanned Aerial Vehicles" OR "UAVs") AND ("warehouse manage" OR "inventory manage")AND ("manufacture" OR "factory") and the first. 105 results (of approximately 500) were manually scanned for pertinence directly from the web, based on the title and abstract.

3.3 Screening and application of inclusion criteria

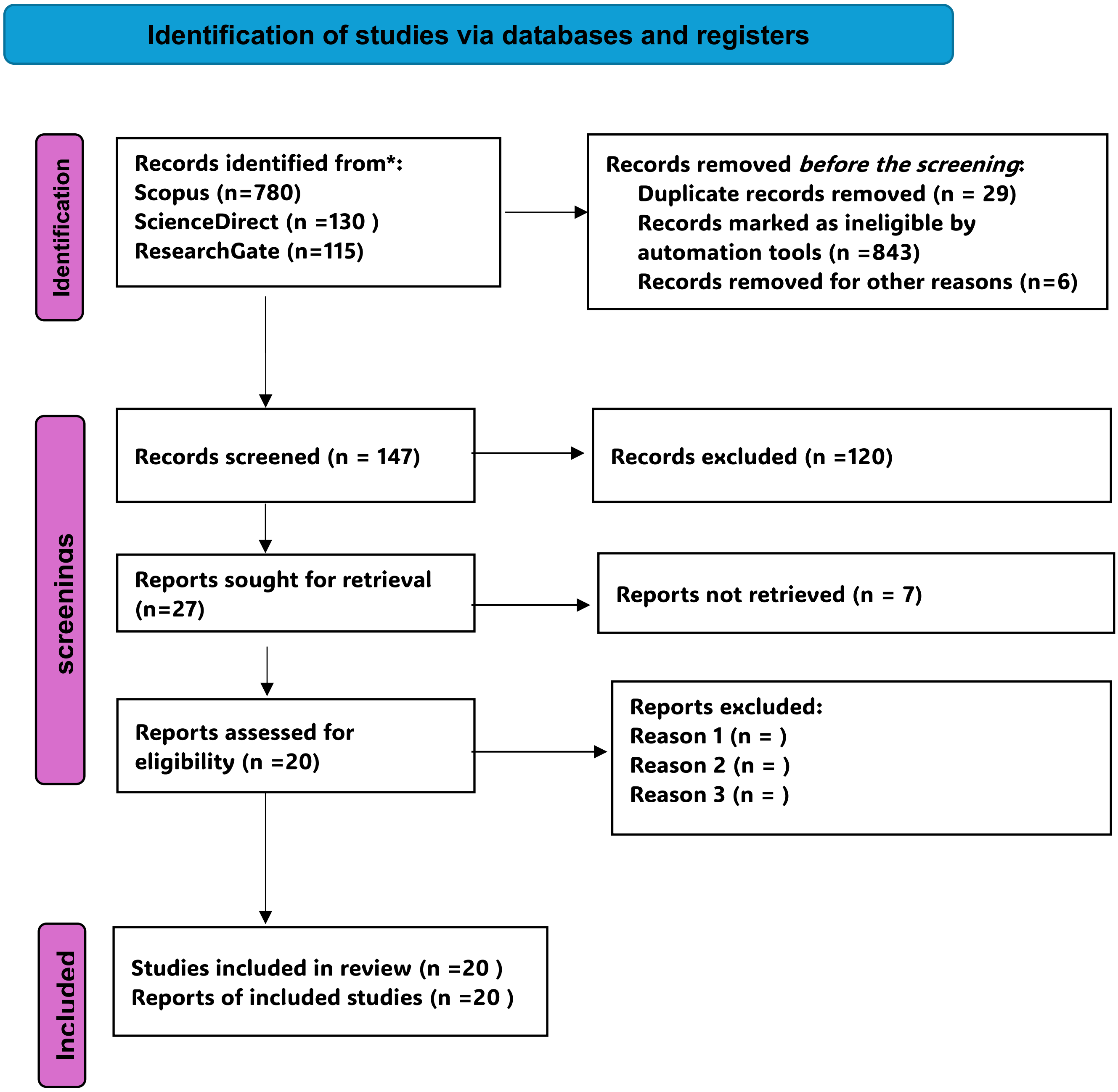
The resulting articles of all databases were inserted in an Excel sheet and duplicates were eliminated before beginning the actual selection process, using the "Find Duplicates" functionality. A total of 29 duplicates were identified using this feature.

and screened initially on the title and abstract against the developed inclusion criteria. No information on reasons for exclusion was collected at this stage. Full texts of studies included in the title and abstract were then sought and screened. I recorded the reason for exclusion for each study at this stage. No inter-reviewer reliability assessment was conducted as I conducted this review as a single reviewer.

A screening for variations of the word 'Drone' in the title and abstract fields ensued which resulted in a total of 843 studies being excluded, this was followed by a manual title and abstract screening which led to a further 120 studies being excluded. This left a total of 20 studies, all of which were successfully retrieved for eligibility assessment. Following the eligibility assessment, a total of 20 eligible studies (c.f. Appendix A) resulted from the entire study selection process, which is depicted in Table 14.

Article based on effectively utilizing a precise project management approach and the value achieved by employing the Agile scrum methodology. In concise terms, the references provide the paper source, article, URL, author name, and publication year for each mentioned article.

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers, and other sources



Source: Adapted from Page et al. (2020)

Table 7.. Prisma Flowchart

3.4 Data Analysis

Data analysis is a critical step in the PRISMA process for conducting systematic reviews. According to the PRISMA statement, data analysis should include the following steps:

1. **Data synthesis:** Data synthesis is the process of combining data from various studies to answer a research question. Meta-analysis is the most common method, but not all systematic reviews include it. Other methods include narrative synthesis, summarizing findings in a narrative format, and qualitative synthesis, analyzing and interpreting qualitative data.
2. **Assessment of heterogeneity:** Heterogeneity refers to the variation in study results, crucial for assessing consistency in meta-analyses
3. **Subgroup analysis:** Subgroup analysis is a method used to analyze the impact of an intervention on different participant groups.
4. **Sensitivity analysis:** Sensitivity analysis is a method used to test the robustness of meta-analysis results by altering assumptions or methods, such as excluding studies with high bias risk, to determine if the meta-analysis results change.
5. **Publication bias:** Publication bias is a phenomenon where studies with positive results are more likely to be published than those with negative results, potentially leading to an overestimation of an intervention's effects. (Page et al., 2021).

The PRISMA guideline allows for the inclusion of new relevant information domains during the data collection process, if based on a scientifically comprehensible rationale. This was the case in this review because, during the data collection process, it was observed that these sources provide insights into safe and reliable handling operations in warehouses. The use of computer-controlled cargo cranes in warehouses allows for quick location and stacking of standard paper trays, as well as accurate retrieval at high speeds. Additionally, the review found that artificial intelligence is being utilized in supply chain cycles to enhance the administration and consistency of the supply chain. The implementation of artificial intelligence in warehouse operations has shown promising results, particularly in optimizing the location of distribution centers and analyzing complex variables involved in material warehouse decisions. Furthermore, the review highlighted the significant impact of artificial intelligence on reducing labor costs and improving logistics efficiency in the warehousing industry (Page et al., 2021). Overall, the systematic review of warehouse automation by drones found that the application of artificial intelligence in logistics warehousing has brought about positive changes in terms of cost reduction and increased efficiency. The systematic review of warehouse automation by drones found that the use of artificial intelligence in supply chain cycles has demonstrated significant improvements in the administration and consistency of the supply chain. The systematic review also revealed challenges in the implementation of artificial intelligence in warehouse automation, such as deficiencies in skills and the mindset of operational management. (Page et al., 2021).

3.5 Thematic synthesis

In the process of systematic reviews, thematic synthesis is a commonly used method of combining qualitative data and in recent times some publications have come up with guidelines on how to use it. As per France et al. (2019), there are three stages of thematic synthesis namely:
1. Free coding of the data: In this phase, it involves systematically reading through primary studies more than once and assigning codes that reflect both their meaning and content.
2. Development of descriptive themes: What this stage entails is putting together similar codes thereby forming descriptive themes that encompass findings across research reports.
3. Generation of analytical themes: This stage extends beyond the above-mentioned descriptive themes to produce new understandings and interpretations based on included study discoveries but goes further into creating new insights to generate knowledge about them.

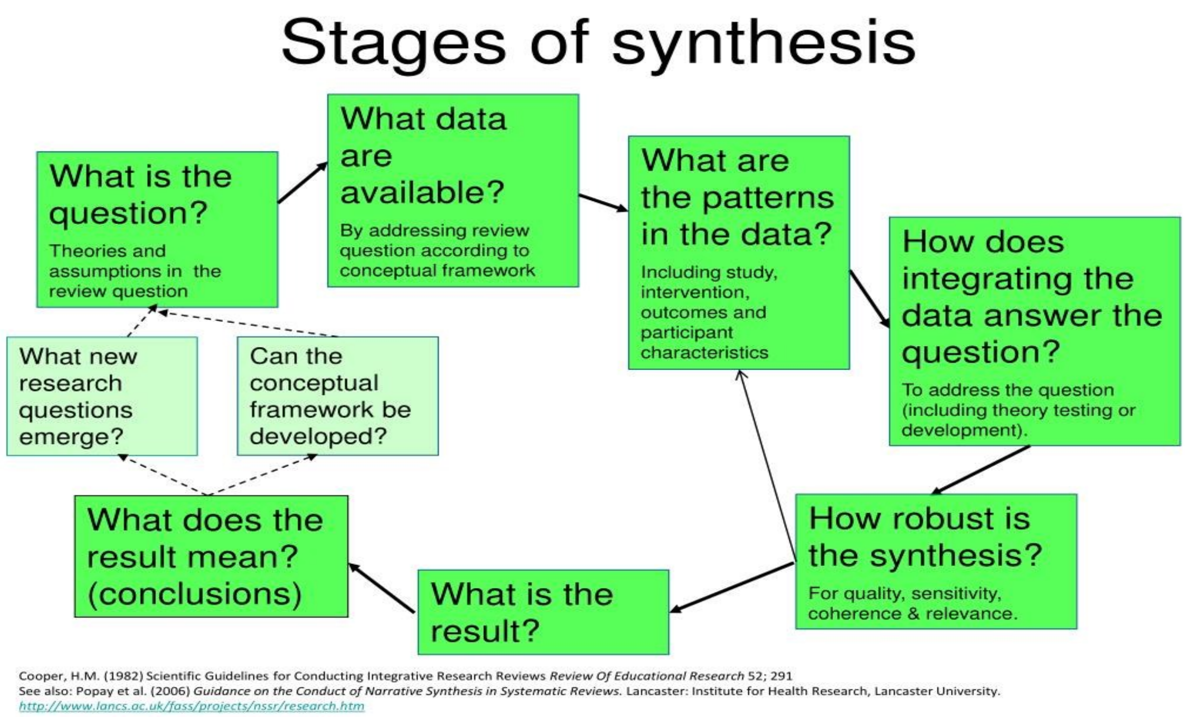


Figure 9. Stages of synthesis findings

3.6 Research Ethics

According to a publication by Noyes et al, ethical considerations in systematic reviews may arise at various stages, including the formulation of the research question, the identification and selection of studies, the extraction and analysis of data, and the dissemination of findings.

Noyes et al. emphasize the importance of ensuring that the review is conducted in a way that is transparent, rigorous, and respectful of the rights and welfare of participants, researchers, and other stakeholders. They highlight several key ethical principles that should be considered in the conduct of systematic reviews, including:

1)Respect for people, 2) Beneficence,3) Justice,4) Transparency.

Noyes et al. also emphasize the importance of obtaining ethical approval for systematic reviews that involve the collection and analysis of primary data and adhering to relevant ethical guidelines and regulations throughout the review process.(Noyes, Booth, & Moore, 2019).

3.6.1 Thematic

I created a bar plot displaying the top 20 most frequent words based on a thematic analysis of the abstracts and conclusions in the dataset. The main ideas covered in the research papers are mapped out thematically by this graphic representation. Let's examine the outcomes:

Top 20 words and their frequencies:

drones: 67
drone: 64
management: 35
delivery: 32
warehouse: 30
industry: 26
inventory: 25
technology: 21
system: 21
From this thematic map, we can identify several key themes and areas of focus in the esearch:

1. Drone Technology: The words "drones" and "drone" are by far the most frequent, indicating that drone technology is the central focus of these papers.
2. Warehouse and Inventory Management: "warehouse," "management," and "inventory" are prominent, suggesting a strong emphasis on applying drone technology to warehouse operations and inventory control.

3. Logistics and Delivery: "delivery" and "logistics" appear frequently, highlighting the importance of drones in improving supply chain and delivery processes.
4. Industry Applications: The presence of "industry" suggests that many papers discuss the industrial applications of drone technology, possibly in the context of Industry 4.0.
5. Technological Systems: Words like "technology," "system," and "operations" indicate discussions about the technological aspects and operational integration of drones.
6. Research Focus: Terms such as "study," "review," and "literature" reflect the academic nature of these papers, likely to include literature reviews and case studies.
7. Supply Chain: The word "supply" suggests that supply chain management is a significant area of application for drone technology.
8. Challenges and Issues: The presence of "challenges" and "issues" indicates that the papers also address the difficulties and potential problems associated with implementing drone technology in warehouses and logistics.

This thematic map provides a clear primarily focus on the application of drone technology in warehouse management, inventory control, and logistics, with a focus on potential benefits and challenges in industry applications, particularly in supply chain management and delivery operations.

Figure 10 . Thematic map

CHAPTER 4

4. RESULT

4.1 Paper Quality Assessments

As part of the identification method, seventy-one publications were chosen for in-depth examination from the initial electronic databases search – as shown in PRISMA Diagram 1 above, in chapter three. Initially, twenty-nine duplicate records, and because of the exclusion criteria, nine hundred sixty-nine were removed, and seven articles were not retrieved. Therefore, only twenty of the initial records were selected for this study and reviewed by the author to see if the focus matches the study goals. This was followed by assessing their quality on Scopus, and others referenced all the papers. To conduct a quality assessment of articles on Scopus, the author considered the source's reputation, author credentials, peer review status, citations, and impact factors. It also evaluated the research methodology, literature review, theoretical framework, results, and conclusions.

Table 8, illustrated below, is a comprehensive overview of the correctly labeled

article based on effectively utilizing a precise project management approach and the value achieved by employing the Agile scrum methodology. In concise terms, the references provide the paper source, article, URL, author name, and publication year for each mentioned article.

In this section, we will answer our Research questions. Demography details of published research Types, frequency of publications, and geographical distribution of authors. Classifying our selected primary studies based on their frequency and publication type is a crucial step in our analysis. This procedure facilitates an understanding of the predominant research trends within our research field, providing a window into the collective interests of the wider scholarly community. By examining the frequency of publication occurrences over time and identifying of publications, such as journal and scientific articles as depicted in the following parts.

Table 8. paper assessments

study	Sources	Article	URL	year	Authors
Essay 1	scopus	Applications of Industry 4.0 Technologies in Warehouse Management: A Systematic Literature Review	https://www.scopus.com/record/display.uri?eid=2-s2.0-851636057	2023	Lihle N. Tikwayo and Tebello N. D. Mathaba 2023
Essay 2	scopus	Unmanned aerial vehicles for inventory listing	https://www.scopus.com/record/display.uri?eid=2-s2.0-851190812	2021	Karamitsos G.; Bechtsis D.; Tsolakis N.; Vlachos D. 2021
Essay 3	scopus	Safety Challenges for Integrating U-Space in Urban Environments	https://www.scopus.com/record/display.uri?eid=2-s2.0-851114187	2021	Castro D.G.; Garcia E.V. 2021
Essay 4	scopus	Optimizing Drone delivery: An efficient design for shipper applications	https://www.scopus.com/record/display.uri?eid=2-s2.0-851754572	2024	Rajalingam S.; Kanagamalliga S.; Sakthi Priya K.; Karuppiah N. 2024
Essay 5	scopus	Intelligent Scheduling Algorithms for the Enhancement of Drone-Based Innovative Logistic Supply Chain Systems	https://www.scopus.com/record/display.uri?eid=2-s2.0-851715321	2023	Banjar A.; Jemmali M.; Melhim L.K.B.; Boulila W.; Ladhari T.; Sarhan A.Y. 2023
Essay 6	scopus	Drones for supply chain management and logistics: a review and research agenda	https://www.scopus.com/record/display.uri?eid=2-s2.0-851156028	2021	Abderahman Rejeb, Karim Rejeb, S. Simske, Horst Treiblmaier 2021
Essay 7	scopus	Accelerating Use of Drones and Robotics in Post-Pandemic Project Supply Chain	https://www.scopus.com/record/display.uri?eid=2-s2.0-851602783	2023	AlRushood M.A.; Rahbar F.; Selim S.Z.; Dweiri F. 2023
Essay 8	scopus	Drone Transportation System: Systematic Review of Security Dynamics for Smart Mobility	https://www.scopus.com/record/display.uri?eid=2-s2.0-851533386	2023	S. Ajakwe, Dong- Seong Kim, Jae Min Lee 2023
Essay 9	researchgate	Utilisation of drones in achieving various applications in smart warehouse management	https://www.researchgate.net/publication/369997540_Utilisation_o	2023	Sadia 2023 Samar Ali, Shahbaz Khan, Nosheen Fat ma, Cenap Ozel, Aftab Hussain
Essay 10	siencdirect	Review article: The emerging drone technology and the advancement of the Indian drone business industry	https://www.sciencedirect.com/science/article/pii/S104783102300	2023	Srinivas Reddy Edulakanti a, Sanjeev Ganguly b

study	Sources	Article	URL	year	Authors
Essay 11	siencdirect	Estimation of traffic density from drone-based delivery in very low level urban airspace	https://www.sciencedirect.com/science/article/pii/S096969971930	2020	Malik Doole, Joost Ellerbroek, Jacco Hoe kstra 2020
Essay 12	scopus	Impact of drone delivery on sustainability and cost: Realizing the UAV potential through vehicle routing optimization	https://www.scopus.com/record/display.uri?eid=2-s2.0-850632192	2019	Wen-Chyuan Chiang, Yuyu Li, J. Shang, Timothy L. Urban 2019
Essay 13	scopus	Joint optimization of customer location clustering and drone-based routing for last-mile deliveries	https://www.scopus.com/record/display.uri?eid=2-s2.0-850809817	2020	Salama M.; Srinivas S. 2020
Essay 14	scopus	Safe and Ergonomic Human-Drone Interaction in Warehouses	https://www.scopus.com/record/display.uri?eid=2-s2.0-851463197	2022	Silvia Proia; Graziana Cavone; Antonio Camposeo; Fabio Ceglie; Raffaele Carli; Dotoli 2022
Essay 15	researchgate	Green Warehouse Practice: Critical issues in drone technology adoption	https://www.researchgate.net/publication/369636526_Green_Ware	2023	Environment-behaviour proceedings journal 2023
Essay 16	researchgate	An exploratory study on the use of unmanned aerial vehicles (UAVs) in transportation: drone transportation and its applications	https://www.researchgate.net/publication/364578425_Insansiz_hav	2022	M. Nurullah Turgut, Bilal Şeker 2022
Essay 17	siencdirect	Social, technological, and systemic issues of spreading the use of drones	https://www.sciencedirect.com/science/article/pii/S235214652030	2020	Jakub Kraus, Adam Kleczatský, Šárka Hulínská 2020
Essay 18	scopus	DroneChase: A Mobile and Automated Cross-Modality System for Continuous Drone Tracking	https://www.scopus.com/record/display.uri?eid=2-s2.0-851638499	2023	Yi Wu, Jian Liu, Phuc Nguyen 2023
Essay 19	scopus	UAVs for Business Adoptions in Smart City Environments: Inventory Management System	https://www.scopus.com/record/display.uri?eid=2-s2.0-851592247	2023	Salazar, Franklin Martínez-García, María Sofía de Castro, Angel Chávez-Fuentes, Carla
Essay 20	researchgate	Smart Surveillance Drone – Warehouse Operations	https://www.researchgate.net/publication/371740016_Smart_Surve	2023	Mr. Om BayasMr. Kshitij ModheMr. Aniruddha KulkarniShow , authorsDr. S. V. Chaitanya 2023

4.2 Quality Assessment

Denscombe mentions that Quality assessment must be conducted in a systematic literature review. The method for quality assessment was done as in the paper "Best Practices for Software Development:

A Systematic Literature Review" by Ordoñez-Pacheco et al. (2020), conformant to "the guidelines published **by Garousi et al**.":

Question-Answer each one of the questions according to the primary study characteristics (0: No, 0.5: Partially, 1: Yes)	**Score**
1. What are the cost-benefit implications of integrating drone technology into warehouse management systems?	
2. How can drones aid real-time tracking and monitoring for improved supply chain transparency?	
3. What is the impact of AI-driven drones on workforce dynamics and employment within warehouse operations?	
4. What are the regulatory challenges associated with the use of drones in warehousing, and how can businesses navigate them?	
5. How do drones contribute to sustainability efforts in warehouse management through optimized routing and reduced energy consumption?	

Table 9.Quality Assessment Questions (Garousi et al.)

What are the challenges and limitations associated with the use of drones in warehousing, and how can businesses navigate them?

4.3 Selection of the Corpus

The resulting studies, a total of 20 studies, is detailed in Table 10 including their quality assessment and quality score (c.f. Table 9). 5of the 20 studies scored 5, 7studeis scored 3 and the others under 2 . Overall, the studies were deemed to all be of high quality according to the guidelines by Garousi et al. (c.f. Table 9).

Table 10.Selection of the Corpus with Quality Assessment

study	Sources	Authors/ Year	Article	RQ1 : Cost Benefit	RQ2 : Real Time Tracking	RQ3 : Workforce Dynamic	RQ4 : Regulatory challenges	RQ5 : Sustainability	Quality score
paper 1	2023	Lihle N. Tikwayo and Tebello N. D. Mathaba 2023	Applications of Industry 4.0 Technologies in Warehouse Management: A Systematic Literature Review	0	1	1	1	0	3
paper 2	2021	Karamitsos G.; Bechtsis D.; Tsolakis N.; Vlachos D. 2021	Unmanned aerial vehicles for inventory listing	1	1	0	0	1	3
paper 3	2021	Castro D.G.; Garcia E.V. 2021	Safety Challenges for Integrating U-Space in Urban Environments	0.5	0.5	0.5	0.5	1	3
paper 4	2024	Rajalingam S.; Kanagamalliga S.; Sakthi Priya K.; Karuppiah N. 2024	Optimizing Drone delivery: An efficient design for shipper applications	0	1	0	1	1	3
paper 5	2023	Banjar A.; Jemmali M.; Melhim L.K.B.; Boulila W.; Ladhari T.; Sarhan A.Y. 2023	Intelligent Scheduling Algorithms for the Enhancement of Drone-Based Innovative Logistic Supply Chain Systems	1	1	0	1	0	3
paper 6	2021	Abderahman Rejeb, Karim Rejeb, S. Simske, Horst Treiblmaier 2021	Drones for supply chain management and logistics: a review and research agenda	1	1	1	1	1	5
paper 7	2023	AlRushood M.A.; Rahbar F.; Selim S.Z.; Dweiri F. 2023	Accelerating Use of Drones and Robotics in Post-Pandemic Project Supply Chain	1	1	0	0	1	3
paper 8	2023	S. Ajakwe, Dong-Seong Kim, Jae Min Lee 2023	Drone Transportation System: Systematic Review of Security Dynamics for Smart Mobility	0	1	0	1	0	2
paper 9	2023	Sadia 2023 Samar Ali, Shahbaz Khan, Nosheen Fatma, Cenap Ozel, Aftab Hussain	Utilisation of drones in achieving various applications in smart warehouse management	1	1	1	1	1	5
paper 10	2023	Srinivas Reddy Edulakanti a, Sanjeev Ganguly b 2023	Review article: The emerging drone technology and the advancement of the Indian drone business industry	1	0	0	1	0	2

study	Sources	Authors/ Year	Article	RQ1 : Cost Benefit	RQ2 : Real Time Tracking	RQ3 : Workforce Dynamic	RQ4 : Requlatory challenges	RQ5 : Sustainability	Quality score
paper 11	2020	Malik Doole, Joost Ellerbroek, Jacco Hoekstra 2020	Estimation of traffic density from drone-based delivery in very low level urban airspace	1	1	1	1	1	5
paper 12	2019	Wen-Chyuan Chiang, Yuyu Li, J. Shang, Timothy L. Urban 2019	Impact of drone delivery on sustainability and cost: Realizing the UAV potential through vehicle routing optimization	1	0	1	0	0.5	2.5
paper 13	2020	Salama M.; Srinivas S. 2020	Joint optimization of customer location clustering and drone-based routing for last-mile deliveries	1	1	1	1	1	5
paper 14	2022	Silvia Proia; Graziana Cavone; Antonio Camposeo; Fabio Ceglie; Raffaele Carli; Dotoli 2022	Safe and Ergonomic Human-Drone Interaction in Warehouses	1	0	0	1	0	2
paper 15	2023	Environment-behaviour proceedings journal 2023	Green Warehouse Practice: Critical issues in drone technology adoption	1	1	0	0	1	3
paper 16	2022	M. Nurullah Turgut, Bilal Şeker 2022	An exploratory study on the use of unmanned aerial vehicles (UAVs) in transportation: drone transportation and its applications	1	1	1	1	1	5
paper 17	2020	Jakub Kraus, Adam Kleczatský, Šárka Hulínská 2020	Social, technological, and systemic issues of spreading the use of drones	0	0	1	1	0	2
paper 18	2023	Yi Wu, Jian Liu, Phuc Nguyen 2023	DroneChase: A Mobile and Automated Cross-Modality System for Continuous Drone Tracking	0	1	0	1	0	2
paper 19	2023	Salazar, Franklin Martinez-García, María Sofía de Castro, Angel Chávez-Fuentes, Carla 2023 Cazorla, María Ureña-	UAVs for Business Adoptions in Smart City Environments: Inventory Management System	1	0	0	0	0	1
paper 20	2023	Mr. Om BayasMr. Kshitij ModheMr. Aniruddha KulkarniShow , authorsDr. S. V. Chaitanya 2023	Smart Surveillance Drone – Warehouse Operations	0	1	1	0	0	2

4.4 Addressing the Research Questions

4.4.1 Distribution of Findings per Research Question

Here is a pie chart showing the distribution of unique findings across each research question. This provides insight into how the research findings are distributed across different themes or questions, highlighting areas of focus.

This analysis reveals that the workforce effect and sustainability receive relatively less emphasis in research, with real-time tracking and cost-benefit analysis receiving most of the attention. While still a major concern, regulatory issues are not given the same priority as real-time tracking.

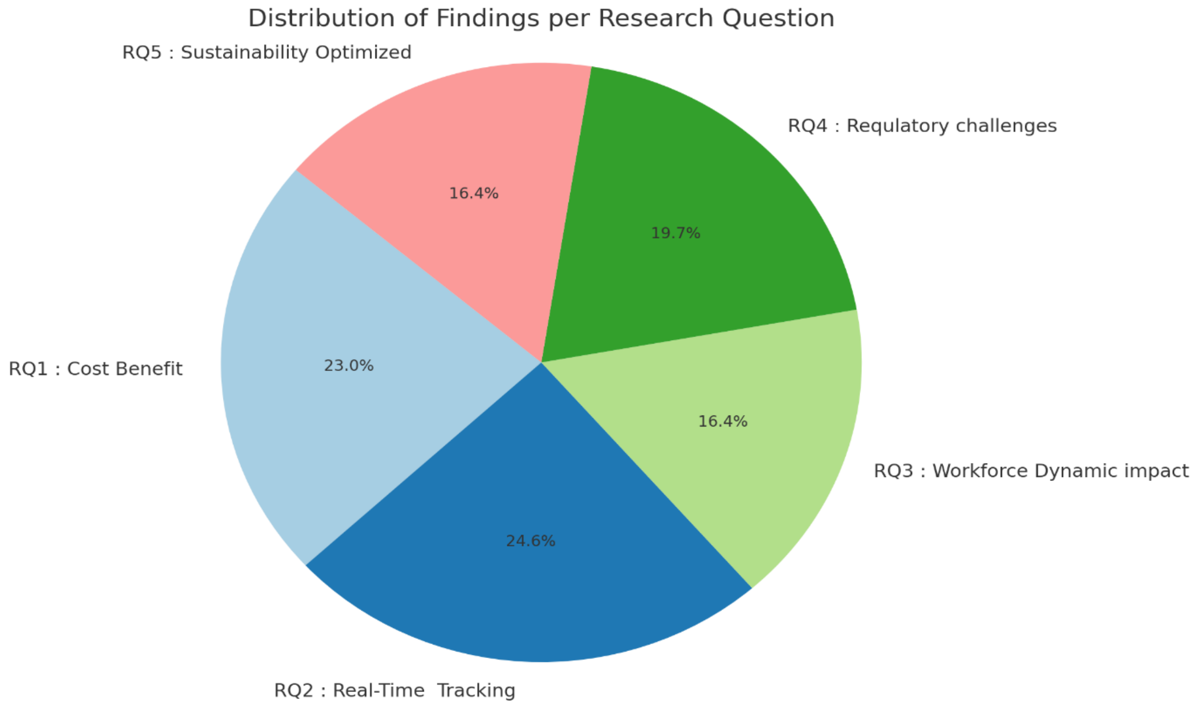


Figure 11. Distribution findings focus on research questions

4.4.2 Number of Essays per Research Question

Here is a bar chart showing the number of essays associated with each research question. With almost 14 essays apiece, RQ2: Real-Time Tracking and RQ4: Regulatory Challenges have the most, demonstrating that they are both thorough topics.

RQ1: Cost-benefit follows closely, indicating that, with 13 essays, it is still another important topic of concentration.

There are just about 11 essays in RQ5: Sustainability Optimized, which suggests a moderate level of research interest.

RQ3: The least number of essays (about ten) is related to Workforce Dynamic Impact, suggesting that this field may have received less attention than the others.

According to this distribution, the two biggest worries are real-time tracking and regulatory issues. The workforce impact, despite its significance in technological improvements, receives the least attention.

. Essay focuses on research questions

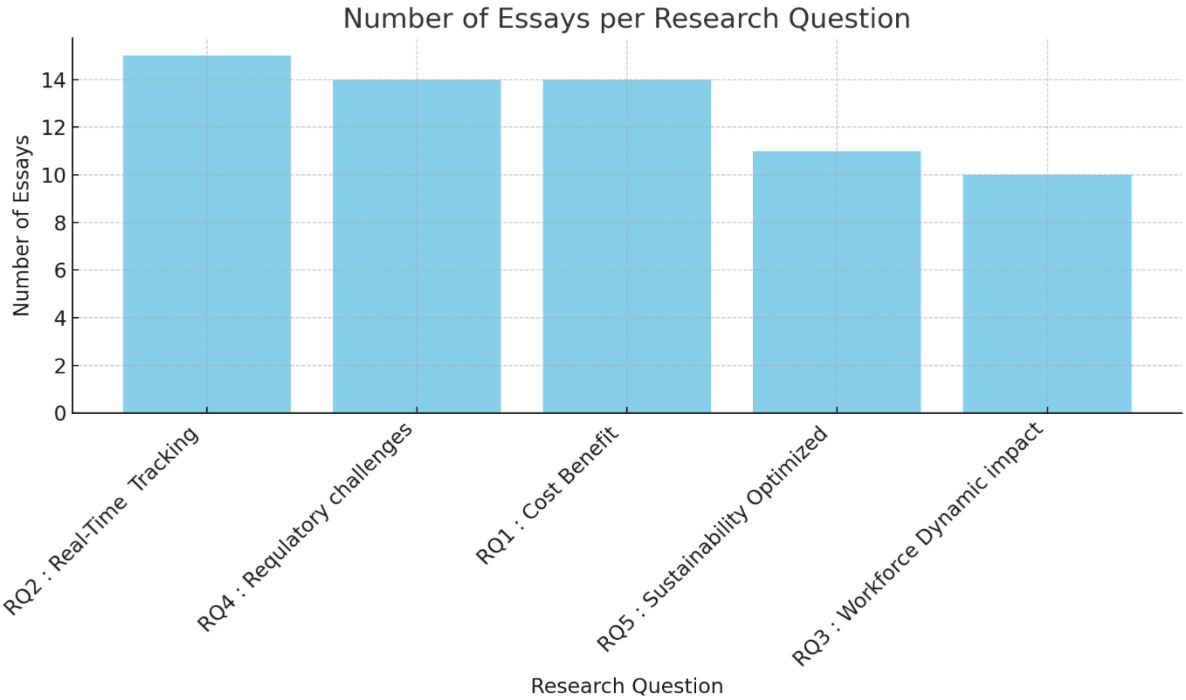


Figure 12. The essay focuses on research questions

4.4.3 Analysis of Publishing Years

The research on Warehouse Management Systems (WMS) and sustainability has shown varying levels of activity. In 2019, 2024, 5% of publications were based on WMS, while 2020 and 2021 contributed 15% and 15% respectively. In 2022, 10% of publications were based on WMS, while in 2023, 50% were based on WMS, indicating a significant surge in interest and research activity on these topics.

This trend suggests that interest in WMS and sustainability grew significantly from 2019 to 2020. After a dip in 2021, the interest peaked in 2023, followed by a drop in 2024. The lower number in 2024 could be due to incomplete data for the year or less research activity at the time of analysis.

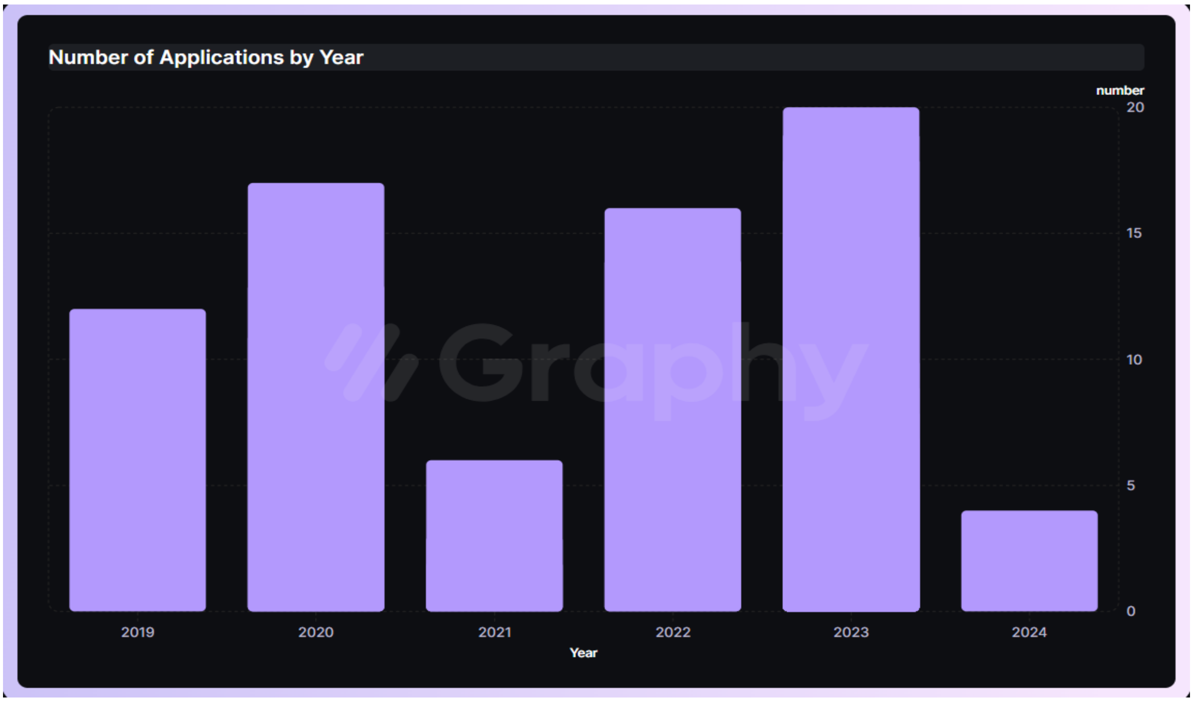


Figure 13. The number of publications discussing WMS and sustainability topics per year.

4.4.4 Research questions evolved over the years from 2019 to 2024.

● Cost Benefit (RQ1): Cost-benefit analysis became more and more popular beginning in 2019 and reaching a peak with a count of six in 2023. Data for 2024 is not available.

● Real-Time Tracking (RQ2): A count of eight indicates a substantial surge in 2023, showing a growing interest in this topic; nevertheless, in 2024, the count declined drastically.

Workforce Dynamic Impact (RQ3): With a few minor oscillations, interest in this field remained largely steady, reaching a high in 2020 and 2023.

● Regulatory Challenges (RQ4): This topic trended similarly to RQ1, reaching a peak of 6 in 2023 before beginning to decline in 2024.

● Sustainability Optimized (RQ5): Over the years, there has been a moderate amount of interest in sustainability, with a minor surge in 2021 and 2023.

Figure 14. Research question over the *years.*

Conclusion and Insights

●Peak Year: 2023 was a significant year for research focus, especially for cost-benefit analysis and real-time tracking.

●Decline in 2024: A noticeable decline in interest across most research questions in 2024 suggests a shift in research priorities or emerging new topics not captured in the data.

4.4.5 Comprehensive Review of Methods Used, Geography, year.

This table displays the geographical focus, study techniques, and technology developments of the investigations vary widely. Computational experiments, mixed-method methods, and rigorous literature reviews are some of the methodologies that are used. Every study provides a different perspective on the advantages and disadvantages of deploying drones for contemporary warehouse and logistics operations.

Table 11. A comprehensive review of Method used, country published, region with title

ESSAY	Authors	Title	Year	Method	Country	Region(s)
1	*Lihle N. Tikwayo *Tebello N. D. Mathaba *	Applications of Industry 4.0 Technologies in Warehouse Management: A Systematic Literature Review	2023	systematic literature review methodology	Africa , North America,Asia, China, Saudi Arabia,Pakistan, India	north america
2	Karamitsos G.; Bechtsis D.; Tsolakis N.;	Unmanned aerial vehicles for inventory listing	2021	development and implementation	Greece	EUROPE
3	Castro D.G.; Garcia E.V.	Safety Challenges for Integrating U-Space in Urban	2021	qualitative and quantitative	United States of	USA
4	Rajalingam S.; Kanagamalliga S.; Sakthi Priya K.; Karuppiah N.	Optimizing Drone delivery: An efficient design for shipper applications	2024	system design	India	ASIA
5	Banjar A.; Jemmali M.; Melhim L.K.B.;	Intelligent Scheduling Algorithms for the Enhancement of Drone-Based Innovative Logistic Supply Chain Systems	2023	computational experiments and algorithm	Saudi Arabia	ASIA
6	Abderahman Rejeb, Karim Rejeb, S. Simske,	Drones for supply chain management and logistics: a review and research agenda	2021	Systematic Literature Review.	Brazil, and China	EUROPE
7	AlRushood M.A.; Rahbar F.; Selim S.Z.; Dweiri F.	Accelerating Use of Drones and Robotics in Post-Pandemic Project Supply Chain	2023	statistical modeling, case studies, and literature reviews.	South Korea.	ASIA
8	S. Ajakwe, Dong- Seong Kim, Jae Min Lee	Drone Transportation System: Systematic Review of Security Dynamics for Smart Mobility	2023	PRISMA-SPIDER Methodology	India	ASIA
9	Sadia Samar Ali, Shahbaz Khan, Nosheen Fatma, Cenap Ozel, Aftab Hussain	Utilisation of drones in achieving various applications in smart warehouse management	2023	Mixed-Method Approach combining Fuzzy Delphi Method, Graph Theory Matrix Approach (GTMA), and Logistic	Saudi Arabia,India	ASIA
10	Srinivas Reddy Edulakanti a, Sanjeev Ganguly b	T1 - Review article: The emerging drone technology and the advancement of the Indian drone business industry	2023	Systematic Literature Review (SLR)	India	ASIA
11	Malik Doole, Joost Ellerbroek, Jacco Hoekstra	T1 - Estimation of traffic density from drone-based delivery in very low level urban airspace	2020	Traffic Demand Estimation Framework combined with a Case Study	Germany, the UK, France, the Netherlands, and Belgium	EUROPE

12	Wen-Chyuan Chiang, Yuyu Li, J. Shang, Timothy L. Urban	Impact of drone delivery on sustainability and cost: Realizing the UAV potential through vehicle routing optimization	2019	Mixed-Integer Linear Programming (MILP) Green Routing Model	Taiwan	USA
13	Salama M.; Srinivas S.	Joint optimization of customer location clustering and drone-based routing for last-mile deliveries	2020	Mathematical Programming Model	United States	USA
14	Silvia Proia; Graziana Cavone; Antonio Camposeo; Fabio Ceglie; Raffaele Carli; Mariagrazia	Safe and Ergonomic Human-Drone Interaction in Warehouses	2022	Speed and Separation Monitoring (SSM) Methodology, Rapid Upper Limb Assessment	Italy	EUROPE
15	Environment-behaviour proceedings journal	Green Warehouse Practice: Critical issues in drone technology adoption	2023	primarily qualitative	Malaysia.	ASIA
16	M. Nurullah Turgut, Bilal Şeker	An exploratory study on the use of unmanned aerial vehicles (UAVs) in transportation: drone transportation and its applications	2022	Active Learning Techniques	Turkey	ASIA
17	Jakub Kraus, Adam Kleczatský, Šárka Hulínská	Social, technological, and systemic issues of spreading the use of drones	2020	qualitative research methods	Prague	EUROPE
18	Yi Wu, Jian Liu, Phuc Nguyen	DroneChase: A Mobile and Automated Cross-Modality	2023	experimental research methods	Texas	USA
19	•Gabriel Râzvan •Radu Boboc •Albert Godina •Dimitris Smalcerz •Mourtzis	UAVs for Business Adoptions in Smart City Environments: Inventory Management System	2023	combination of literature review and experimental research	Spain	EUROPE
20	•Mr. Om Bayas •Mr. Kshitij Modhe	Smart Surveillance Drone – Warehouse Operations	2023	Experimental/System Evaluation	India	ASIA

- The data presented in this table demonstrates the increasing global interest in drone logistics and warehouse management. The numerous approaches used and the extensive geographic reach highlight the worldwide initiatives to optimize supply chains through the use of cutting-edge drone technologies. These studies provide insightful information on the potential applications of drone-based logistics, ranging from safety concerns to delivery system optimization.

4.4.6 Distribution of method used

The percentage distribution of the various study methods is displayed in the graphic, with each method accounting for around 5% of the total. According to the chart, the research projects that are part of this dataset employ a wide range of nearly equally, demonstrating a methodological approach that is both broad and diversified. This diversity contributes to the provision of many viewpoints and thorough assessments on the subjects covered. Depending on the goals of the study, the researchers employ both qualitative and quantitative methods; no one approach seems to be dominant.

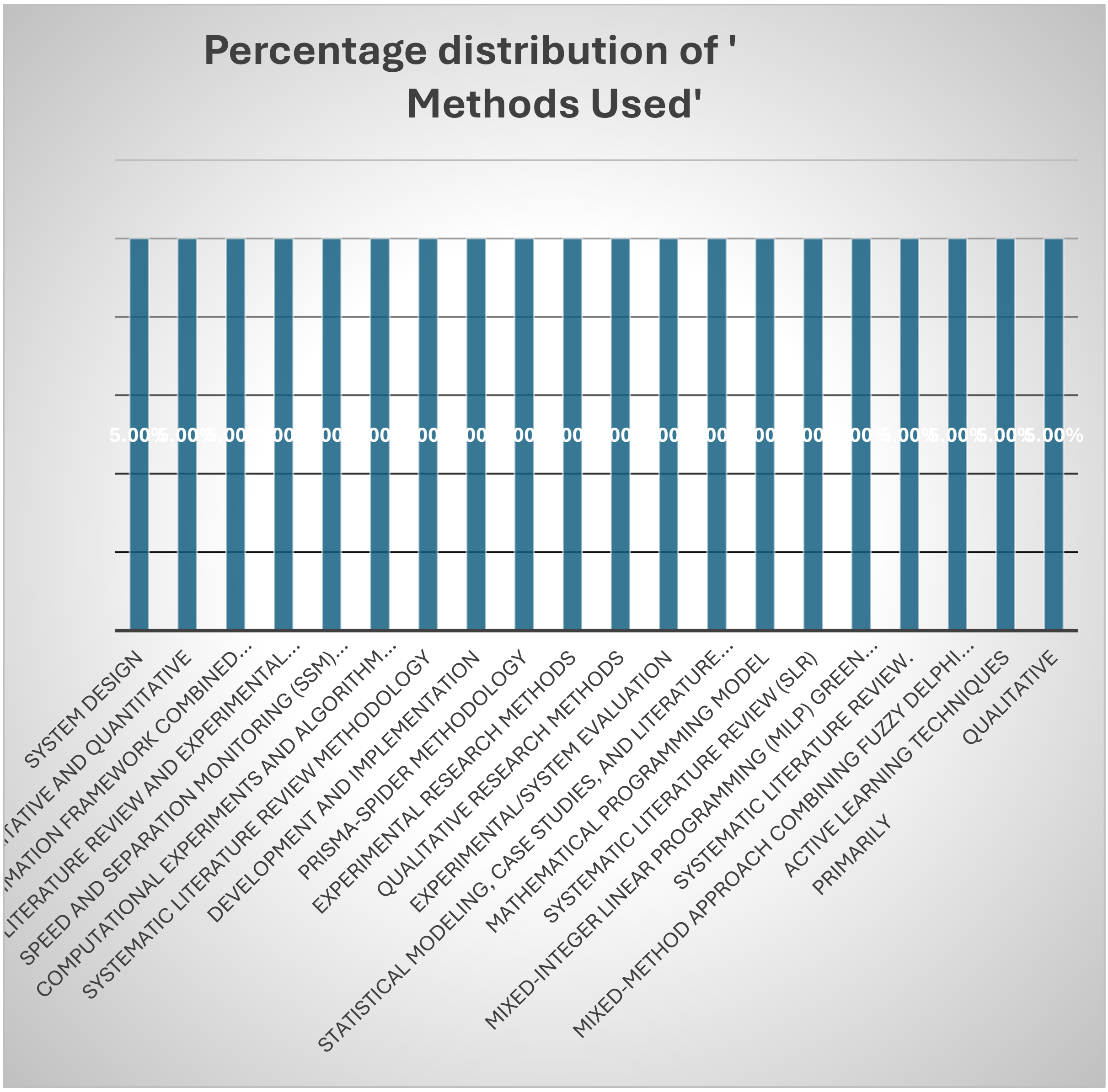


Figure 15. Method used distribution

4.4.7 Geography

The corpus of studies includes a diverse range of authorship, with 9 studies originating from authors based in Asia, 6 from authors in Europe, and 4 from authors in South America. Additionally, 1 study was co-authored by researchers from both Africa and South America. The methodologies employed in these studies are highly varied, spanning techniques such as systematic mapping, Delphi studies, survey research, and grounded theory, among others (as referenced in Table 11). Some studies have adopted mixed methods approaches, incorporating semi-structured interviews alongside surveys for exploratory designs, or combining multiple case studies with techniques like questionnaires, non-participative observations, semi-structured interviews, and archival data analysis.

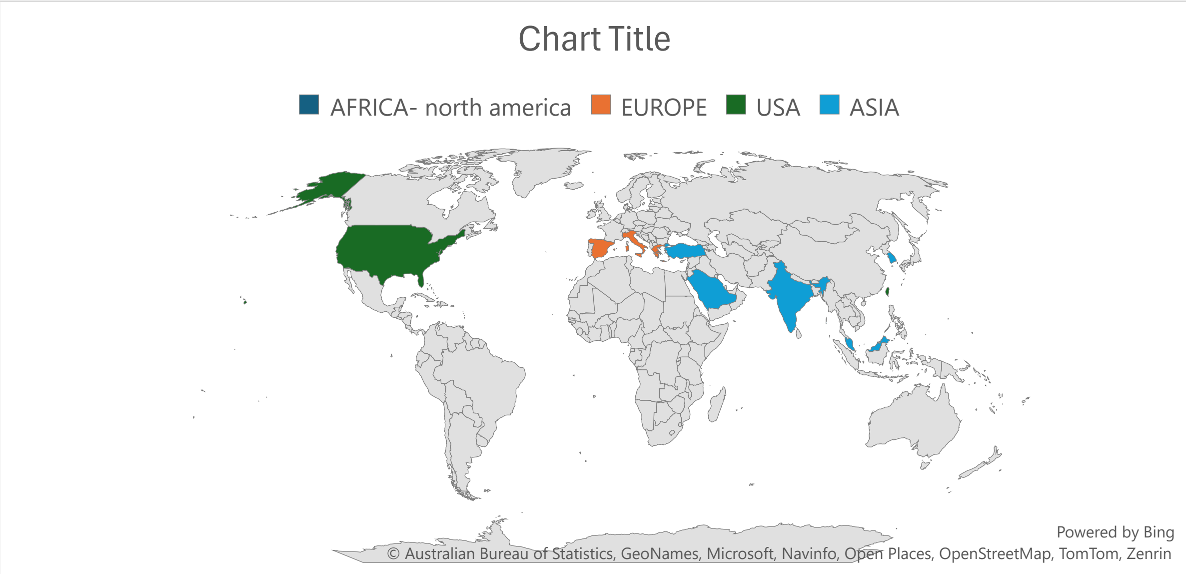


Figure 16.Selected Geography region

4.5 Descriptive Results

Table 11 shows the main articles' details (authors, titles, published years) as well as reference citation numbers. Articles were assigned Roman index numbers from I to XX to ease the representation of a reference to one of the 20 articles in the follow-up tables and figures illustrations. The appendix gathers the entire article's information.

Table 12 .20 Brief articles information and Essay

ESSAY	Refrences	Authors	Title	Year
I	[33]	*Lihle N. Tikwayo *Tebello N. D. Mathaba *	Applications of Industry 4.0 Technologies in Warehouse Management: A Systematic Literature Review	2023
II	[5]	Karamitsos G.; Bechtsis D.; Tsolakis N.; Vlachos D.	Unmanned aerial vehicles for inventory listing	2021
III	[59]	Castro D.G.; Garcia E.V.	Safety Challenges for Integrating U-Space in Urban Environments	2021
IV	[35]	Rajalingam S.; Kanagamalliga S.; Sakthi Priya K.; Karuppiah N.	Optimizing Drone delivery: An efficient design for shipper applications	2024
V	[29]	Banjar A.; Jemmali M.; Melhim L.K.B.; Boulila W.; Ladhari T.; Sarhan A.Y.	Intelligent Scheduling Algorithms for the Enhancement of Drone-Based Innovative Logistic Supply Chain Systems	2023
VI	[55]	Abderahman Rejeb, Karim Rejeb, S. Simske, Horst Treiblmaier	Drones for supply chain management and logistics: a review and research agenda	2021
VII	[25]	AlRushood M.A.; Rahbar F.; Selim S.Z.; Dweiri F.	Accelerating Use of Drones and Robotics in Post-Pandemic Project Supply Chain	2023
VIII	[151]	S. Ajakwe, Dong-Seong Kim, Jae Min Lee	Drone Transportation System: Systematic Review of Security Dynamics for Smart Mobility	2023
IX	[63]	Sadia Samar Ali, Shahbaz Khan, Nosheen Fatma, Cenap Ozel, Aftab Hussain	Utilisation of drones in achieving various applications in smart warehouse management	2023
X	[35]	SrinivasReddy Edulakanti a, Sanjeev Ganguly b	T1 - Review article: The emerging drone technology and the advancement of the Indian drone business industry	2023
XI	[102]	Malik Doole, Joost Ellerbroek, Jacco Hoekstra	T1 - Estimation of traffic density from drone-based delivery in very low level urban airspace	2020

XII	[69]	Wen-Chyuan Chiang, Yuyu Li, J. Shang, Timothy L. Urban	Impact of drone delivery on sustainability and cost: Realizing the UAV potential through vehicle routing optimization	2019
XIII	[35]	Salama M.; Srinivas S.	Joint optimization of customer location clustering and drone-based routing for last-mile deliveries	2020
XIV	[25]	Silvia Proia; Graziana Cavone; Antonio Camposeo; Fabio Ceglie; Raffaele Carli; Mariagrazia Dotoli	Safe and Ergonomic Human-Drone Interaction in Warehouses	2022
XV	[23]	Environmental behaviour proceedings journal	Green Warehouse Practice: Critical issues in drone technology adoption	2023
XVI	[55]	M. Nurullah Turgut, Bilal Şeker	An exploratory study on the use of unmanned aerial vehicles (UAVs) in transportation: drone transportation and its applications	2022
XVII	[15]	Jakub Kraus, Adam Kleczatský, Šárka Hulínská	Social, technological, and systemic issues of spreading the use of drones	2020
XVIII	[23]	Yi Wu, Jian Liu, Phuc Nguyen	DroneChase: A Mobile and Automated Cross-Modality System for Continuous Drone Tracking	2023
XIX	[19]	Gabriel Râzvan Radu Boboc,Albert Godina Dimitris Smalcerz,Mourtzis Franklin Salazar,María Sofía Martínez-García, Angel De Castro Carl Cháve-Fuentes María Cazorla	UAVs for Business Adoptions in Smart City Environments: Inventory Management System	2023
XX	[5]	Mr. Om Bayas,Mr. Kshitij Modhe Mr. Kulkarni,Mr. Londhe S. Chaitanya	Smart Surveillance Drone – Warehouse Operations	2023

4.6 Summary of Main Results

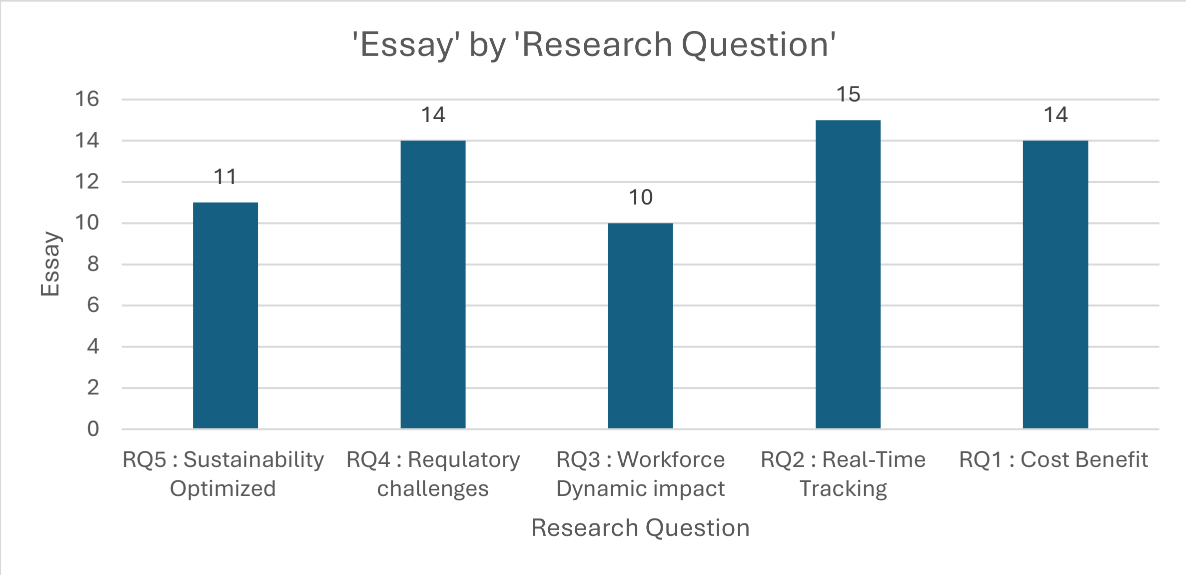


Figure 17.Thematic analysis – themes, sub-themes, codes and relevant studied papers.

Exploring Solutions: Themes, Tools, and Challenges This section analyzes the state of the research, including three research questions.

RQ1 : Cost Benefit

Key Main content of RQ1:

Drones eliminate downtime, increase productivity, and save labor expenses through continuous inventory monitoring. With the potential to reach EUR 10 billion yearly by 2035, they might make a major contribution to the European market. Drones reduce transportation costs in logistics, particularly for last-mile delivery. To reduce operating expenses and enhance tracking, the Drone-Based Capital Project Optimization Model (DBCPOM) is being suggested. It incorporates cutting-edge technologies. It is more economical to rent drones than to buy them, especially in developing nations like India. Interaction between humans and drones in warehouses improves safety and lowers production costs. Drones with advanced technology facilitate the integration of smart cities and logistics networks by offering real-time data that improves decision-making and cost efficiency.

Key Finding of RQ1:

The results demonstrate how drones drastically save operating costs and improve safety in supply chain operations by reducing the chance of injuries. They improve productivity across a range of industries, including construction and logistics, and allow for round-the-clock inventory management. By 2050, it is anticipated that the European drone market will grow significantly due to rising demand and possible cost reductions. When it comes to drone application optimization, the MID algorithm's success rate of 87.7% is quite remarkable.

Additionally, technology lowers fuel usage, routing costs, and carbon emissions. Drones provide important assistance in smart city environments by improving inventory accuracy and streamlining warehouse management processes. Drones are being used by businesses more and more to improve operational efficiency and client demand response. Notwithstanding the noteworthy advantages, further investigation is required to assess the effects on performance and client contentment. The drone business is expected to grow at a compound annual growth rate (CAGR) of 13.62%, which points to potential investment opportunities and a push for wider industrial use.

Drone Utilization in Warehouse Operations

• Proposed emulation tool for drone operations in warehouse inventory management.

• MID algorithm outperformed other algorithms with an 87.7% success rate.

Drones in Supply Chain Management (SCM)

• Drones offer benefits in SCM including reduced delivery times, cost savings, and enhanced flexibility.

• Use leads to increased sustainability, making drones a transformative logistics technology.

Comparative Method Analysis

• Traditional methods compared against new approaches, revealing significant time and cost savings.

Global Market & Industry Trends

• The global drone industry expanding due to technological advancements and growing consumer interest.

Impact on Urban Traffic & Green Routing

• Drones alleviate urban traffic congestion and offer sustainable transportation options.

Optimized Delivery Strategies

• Optimized clusters, focal points, and truck routing strategies for efficient delivery.

Human-Drone Interaction

• Studies show safe and ergonomic human-drone interactions improve operator safety and operational efficiency.

Future of Drone Logistics: Drone transportation in logistics is rapidly increasing.

Integration with Advanced Systems

• SCADA system is used for monitoring box locations, controlling relocations, and managing stacker cranes.

RQ2: Real-Time Tracking

Key Main content of RQ2:

Real-Time Tracking in Warehouse Management: Talks about how real-time tracking can improve operational efficiency and transparency in warehouse management systems.

Drones in Inventory Management: By enabling real-time inventory tracking, drones enhance accuracy and responsiveness.

Continuous Monitoring: Stakeholders can efficiently manage inventory levels with the use of the suggested system's web-based interface, which offers monitoring around-the-clock.

Advanced Drone Traffic Tracking Systems: Highlights the necessity of employing strong digitalization and automation in advanced tracking systems to properly manage the increasing amount of drone traffic.

Drone delivery with GPS Integration: GPS technology guarantees real-time package tracking, providing dispatchers and clients with up-to-date information.

Intelligent Monitoring System: Offers a clever console for real-time drone monitoring and task rescheduling.

Automation in Logistics: Immediate delivery status updates and increased efficiency are made possible by real-time tracking, which strengthens automation.

DBCPOM Model in Construction Sites: Describes the DBCPOM model, which uses drones fitted with RFID and smart sensors to track materials in real-time.

Drone transportation systems that use real-time tracking ensure operational preparedness and communication resilience while tackling security issues.

Inventory management: One major benefit of integrating drones is real-time tracking for inventory management, which facilitates quicker decision-making and precise stock-level data.

Systems for Unmanned Traffic Management (UTM): promotes effective route planning and safe drone operations in urban airspace.

Efficiency in the Delivery of Drones: Improved route modifications and increased operational effectiveness are made possible by real-time tracking.

RFID and IoT for Inventory Management: Drones give real-time information on stock levels, enhancing logistics and minimizing inconsistencies in stock levels.

Improved Customer Happiness and Visibility: Live updates provided by real-time tracking result in improved logistics management and increased customer happiness.

Drone Chase System: Tracks drones in real-time, even in low visibility, using both visual and auditory cues.

Automated Inventory Checks: By utilizing live video feeds and barcode scanning, drones can conduct inventory checks automatically, eliminating the need for human inspections.

Key Finding of RQ2:

Drones and other Industry 4.0 technologies improve warehouse management decision-making, real-time data availability, and process efficiency while giving businesses a competitive edge through digital integration. Using GPS tracking and facial recognition technology, drones enhance delivery efficiency and provide precise, real-time inventory listing.Drone logistics shown potential in disaster response scenarios, and the MID algorithm proved to be highly accurate and efficient. Supply chain visibility and inventory management are enhanced by drones that are AI-integrated. Among the difficulties are the demands for better cybersecurity and safety measurements, as well as higher traffic congestion.

Drones have been shown to be useful for reaching hard-to-reach places, conducting surveillance missions, and conducting inspections. Portable systems like as Drone Chase provide real-time monitoring by combining audio and visual inputs. These developments demonstrate how quickly UAVs have moved from military to commercial use, improving logistics operations both indoors and outside. Drone-Based Logistics System: Efficiency, Real-time Data, Safety, and Regulatory Concerns:

• Industry 4.0 technologies and drones enhance process efficiency and provide real-time data.

• The system supports continuous 24/7 drone operations for accurate inventory management.

• Safety and regulatory concerns require defined safety metrics and operational insights.

• Drones with facial recognition and control models improve delivery efficiency and accuracy.

• The MID algorithm outperforms others in minimizing task completion time.

• Challenges include managing dynamic obstacles and coordinating trucks and drones.

• Adoption barriers exist for warehouse operators due to complex operations and limitations.

• Drones enhance inspections, surveillance, and stock through autonomous flights.

• The Drone Chase System improves tracking and future potential for multiple drones.

RQ3: Workforce Dynamic impact

Key Main content of RQ3:

Traditional employment responsibilities may become less relevant as drone technology becomes more integrated into sectors like aviation, agriculture, and logistics, especially in areas like air traffic management and delivery. However, it's anticipated that prospects for drone maintenance, operation, and regulatory compliance will increase.

Key points include:

• **Employment Transformation:** It's expected that the use of drones would cause employment rolls to change to more strategic ones, requiring employees to become accustomed to new procedures and technologies.

• **Skill Development:** To properly manage and operate drone technologies, employees will require retraining, which will result in a more trained workforce.

• **Increased production:** By automating dangerous and repetitive activities, drones free up human workers to concentrate on more complicated duties, resulting in increased production.

• **Safety Enhancements:** By taking over risky delivery duties, drone adoption is predicted to lower workplace accidents.

• **Flexibility and Collaboration:** Drones optimize resource management by enabling more flexible work schedules and fostering collaboration between human workers and drone technology.

Key Finding of RQ3:

Strong management support and a solid implementation strategy are essential for the successful integration of drone technology into warehouse management. Drones are being used extensively in inventory management, inspections, and intra-logistics. To ensure their successful integration, nine essential enablers have been identified. These facilitators include value quality, compatibility, and operational effectiveness.

The application of logistic regression analysis helps customize drone deployment to satisfy consumer demand in certain target markets. According to the report, there will be a lot of drone traffic in cities, which means that logistical operations must be enhanced. When it comes to improving operational efficiency, a joint optimization method is superior to sequential approaches.

However, many systemic, technological, and societal problems are impeding the drone industry's expansion. Drones are acknowledged as workable options for inventory audits and part transfers in manufacturing settings, notwithstanding these obstacles.

Key points include:

• Skilled Workforce: The deployment of a system requires skilled workers.

• Resilience engineering: reduces the hazards connected to self-governing systems.

• Humanitarian logistics: Enhances delivery effectiveness while assisting humanitarian endeavors.

• Intra-Logistics Applications: Enables effective parts transfer, stock checks, and inventory management.

• Anticipated Future: By 2035, Paris will have seen over 63,596 drone delivery operations.

• Operational Efficiency: Tasks are automated, reducing the need for human operators.

• Advances in AI: Expands the potential of drones, particularly in e-commerce.

• Stakeholder Influence: Affects drone technology acceptability and development.

RQ5: Sustainability Optimized

Key Main content of RQ5:

Drone integration in logistics and inventory management greatly improves sustainability in several ways. Drones have a positive social and environmental impact. They minimize the risk of human injuries in warehouses by using rechargeable, eco-friendly batteries, which also lower the carbon footprint of activities. Economically, its automation promotes a sustainable supply chain by lowering human costs and downtime.

Due to their increased energy efficiency over conventional vehicles and possible reduction of carbon emissions, drones help provide more environmentally friendly delivery alternatives. Their more energy-efficient flight paths and intelligent control systems, along with other operational enhancements, allow for faster delivery times.

In line with sustainable development objectives, the DBCPOM model's usage of drones improves resource management and waste reduction in capital projects. When UAV technology develops, it has the potential to drastically cut greenhouse gas emissions and traffic jams, particularly in urban areas. This would help create a greener logistics ecosystem. All things considered, using drones to operate supply chains can help meet sustainability goals and satisfy consumer demands for eco-friendly operations.

Key Finding of RQ5:

Drone operations are evaluated using an emulation tool, backed by a taxonomy of UAV attributes emphasizing the usage of environmentally friendly, rechargeable batteries. The significance of safety measurements and operational insights in urban areas is emphasized by key findings.

Drone delivery performance is greatly enhanced by intelligent control strategies and cutting-edge features. In addition to lowering fuel consumption, carbon emissions, and delivery expenses, drones also minimize the need for human interaction while conducting remote construction site inspections. Delivery efficiency is further enhanced by clustering delivery locations, which maximizes the integration of drones and vehicles. Despite technical challenges such as limited payload and battery life, the study predicts substantial growth in drone transportation by 2030, underscoring the potential for increased efficiency and sustainability.

Key point:

Emulation Tool: An emulation tool showcases several applications in forestry, agriculture, and other industries while evaluating drone operations in warehousing facilities.

Delivery Innovations: Drones could transport packages to particular floors of buildings in the future, increasing efficiency and convenience. Drones improve supply chain management (SCM) by cutting expenses and delivery times while boosting sustainability.

Adoption in Construction: Despite obstacles including laws, battery life, weather, and cybersecurity concerns, the construction industry is progressively implementing drones, artificial intelligence, and robotics to increase operational efficiency.

Urban Traffic Solutions: Drones can reduce traffic in cities and offer environmentally friendly transportation choices.

Creation of Genetic Algorithms: A genetic algorithm was created with the goal of reducing carbon emissions and delivery expenses to maximize truck routing for sustainability.

Fuel Consumption Reduction: The environmental benefits of using UAVs are highlighted by the fact that they can drastically cut emissions and fuel consumption.

Optimal Delivery Techniques: Future research should consider coordinating truck and drone operations at different hub locations in addition to the study's recommendations for optimal delivery clusters and truck routing techniques.

Resolving Adoption Issues: The study attempts to close gaps in the body of knowledge on drone transportation by identifying issues warehouse operators have while implementing drone technology.

Table 13. key point result over research questions

Research Question	RQ1: Cost Benefit	RQ2: Real-Time Tracking	RQ3: Workforce Dynamic impact	RQ4 : Regulatory challenges	RQ5: Sustainability Optimized
code	Cost Reduction	Improved Transparency	Job Automation	Airspace Compliance	Reduced Energy Use
Theme	Cost Efficiency	Supply Chain Transparency	Workforce Automation	Regulatory Barriers	Environmental Sustainability
Paper study	P[2],[P3],[P5],[P6],[P7],P[9].P[10],P[11],P[12],P[13],P[14],P[15],P[16],P[19]	[P1],[P2],[P3],[P4],[P5],[P6],[P7],[P8],[P9],[P11],[P13],[P15],[P16],[P18],[P20]	[P1],[P3],[P6],[P9],[P11],[P12],[P13],[P16],[P17],[P20]	[P1],[P3],[P4],[P5],[P6],[P8],[P9],[10][P11],[14][P13],[P17],[P16],[P18],	[P2],[P3],[P4],[P6],[P7],[P9],[P11],[12][P13],[P15],[P16]
total essay	14	15	10	14	11

Finding	The global drone industry is growing rapidly due to advancements in technology and reduced operational costs.	Real-time data availability improves process efficiency and decision-making.	AI-driven automation is transforming workforce dynamics, especially in industrial sectors.	Privacy concerns and security risks are major regulatory hurdles for drone implementation.	Drones can help optimize last-mile delivery, reducing energy consumption and environmental impact.
Result	Significant cost savings due to automation and technology advancements.	Significant improvements in real-time data access and operational transparency.	Job automation reduces manual labor but requires a robust framework for successful deployment.	Compliance is essential, but regulations may hinder rapid deployment.	Drones offer solutions for urban congestion and sustainable delivery models.
Main content	Explores how drone technologies are reducing costs in various industries, especially through automation.	Discusses the importance of transparency in supply chains and how real-time tracking addresses key inefficiencies.	Highlights the impact of automation on the workforce and the necessary adaptations required for successful implementation.	Focuses on the regulatory landscape and its challenges for the commercial drone industry.	Discusses how drones contribute to environmental sustainability by enhancing delivery efficiency and reducing emissions.
limitation	High life cycle costs and lack of proper frameworks for implementation.	Physical environment and layout challenges can limit the effectiveness of tracking technologies.	The physical environment presents significant hurdles for implementing automation.	High regulatory costs and the need for airspace compliance.	Specific challenges regarding sustainability are not mentioned.
Futu	Assessment of drone integration with existing systems.Integration of drones for quantity surveillance. Improved funding for Industry 4.0 surveys. Exploration of drone technology in warehouse opera.	Improved barcode recognition.Simultaneous drone tracking. Active RFID integration. Drone technology in warehouse operations.	Study on drones' impact on warehouse operations. Examination of drones' influence on organizational performance and customer satisfaction. Research on real-time data processing for inventory management.	Exploring U-space architectures for urban air mobility.Investigating AI model training data availability issues.Studying regulatory frameworks for drone transportation. Exploring social issues affecting drone adoption.	Adapting algorithms for transportation and monitoring. Investigating environmental impacts of drone usage.Exploring energy consumption efficiency.Optimizing drone battery life and charging systems.

CHAPTER 5

5. DISCUSSIONS

5.1 Limitations and Challenges

For the challenges, I organized research question 4 including the challenges of our studies:

RQ4: Regulatory challenges

Key Main content of RQ4:

The integration of drones into warehousing and delivery services faces several key regulatory challenges:

1. **Inadequate Regulations**: The safety and operating standards of the current drone rules, particularly in Europe, are lacking, which makes it difficult for drones to integrate effectively into urban airspaces.
2. **Safety and Compliance**: Companies must
3. handle a variety of intricate safety standards and compliance requirements, such as aviation laws and data protection privacy concerns.
4. **Privacy Concerns**: The deployment of drones presents significant privacy and surveillance challenges, calling for the establishment of explicit policies governing their usage.
5. **Legal and Insurance Issues**: Drone adoption is hampered by uncertainties about liability and insurance coverage for drone activities.
6. **Public Acceptance**: Getting the public's trust is essential since safety and privacy concerns must be addressed.
7. **Needed Collaboration**: To create thorough standards for safe drone operations, businesses, and regulatory agencies must effectively communicate with one another.

Key Finding of RQ4:

There are several obstacles to overcome when integrating drone technology into logistics, including increased security threats, privacy issues, and regulatory compliance. Integration is made more difficult by the incomplete U-space structure, and wider adoption is hampered by the high cost of compliance. India has the potential to become a hotspot for drone technology because to government programs and customer demand. Effective management is challenged by high-density drone traffic. For drone integration in logistics and transportation systems to be successful, social, technological, and systemic constraints must be addressed. Standardization in U-space services is necessary since the current regulatory framework is immature and cannot handle new safety concerns. After a thorough analysis, 700 case studies and 343 pertinent papers supporting cutting-edge approaches like zero-trust architecture to improve drone operations were found.

Challenges of Drone Technology Integration

• Enhanced Security Risks: The use of drone technology raises the possibility of cyberattacks and insufficient defenses against them.

• Absence of rules: The creation and operation of U-space services are governed by a lack of established rules, which results in inconsistent and incompatible developments.

• Regulatory Challenges: The accountability and traceability of drone activities are impacted by the complexity of unifying airspace security standards resulting from disparate municipal regulations.

• Systemic and technological issues: Adoption of drones is hampered by these issues, particularly in heavily populated urban areas.

• Expert Bias and Overlooked Enablers: Drone operating requirements may be complicated by biased identification of important drone integration enablers.

❖ **Are there specific challenges that are commonly associated with certain research questions?**

To determine if specific challenges are commonly associated with certain research questions, I analyzed the titles and research questions to identify recurring themes or terms that might indicate challenges.

Research Questions and Challenge-Related Term Percentages:

- **RQ3: Workforce Dynamic Impact** – 20%
- **RQ5: Sustainability Optimized** – 18.18%
- **RQ4: Regulatory Challenges** – 14.29%
- **RQ1: Cost Benefit** – 14.29%

- **RQ2: Real-Time Tracking** – 13.33%

Research Challenge Analysis

The most difficult aspects of workforce dynamics are integrating new technology with the workforce that already exists. The intricate interactions between environmental, economic, and operational concerns make sustainability optimization difficult as well.

• The study question features regulatory challenges more prominently than titles do.

• Because of their recognized fields or implicit problems, cost-benefit analysis and real-time tracking pose fewer clear challenges in titles.

• A thorough content analysis of the papers is necessary for additional research, and this may involve the use of topic modeling or sophisticated natural language processing.

5.2 Future research

1. Integration with Warehouse Management: To improve productivity and operational efficacy, look into how drones can be easily incorporated into current warehouse management systems.

2. Payload Capacity Enhancements: To enhance delivery and logistics capabilities, concentrate on raising drone payload capacities and operational efficiency.

3. Safety and Compliance Research: To guarantee safe use in a variety of settings, investigate safety precautions and regulatory compliance linked to drone operations.

4. Impact on Labor Dynamics: Research into how workforce requirements and labor dynamics in warehouse environments are impacted by the employment of drone technology.

5. Battery Life Optimization: To increase operational capabilities and decrease downtime, investigate developments in drone battery life and charging technologies.

6. Real-time Data Processing: Examine methods for processing data in real time to improve warehouse operations' tracking precision and inventory management.

CHAPTER 6

Conclusion

In conclusion, this thesis has demonstrated the significant influence of integrating drones and artificial intelligence (AI) on warehouse management. Previous studies' evaluation and analysis have shown how these tools may improve the accuracy, speed, and safety of warehouse operations. AI-powered drones can address long-standing warehousing issues by providing real-time information, reducing errors, and improving process flow.

Towards the Future: Useful Advice and Prospects

With the advancement of AI and drones, the future appears bright. To get rapid results, warehouse managers who are interested in these technologies may begin modestly, possibly by utilizing drones for safety monitoring or inventory inspections. These tools can then be extended to other sections, thus altering the overall operation of the warehouse.

Gaps in Research and Directions for Future Studies

There are still several unknowns, particularly about the expenses and possible laws required for widespread drone use. These topics could be investigated further, assisting businesses and authorities in developing precise regulations. It would also be beneficial to investigate the long-term economic effects as well as the potential employment effects of AI and drones.

AI and drones complement today's drive for more environmentally friendly methods. These technologies can contribute to more sustainable warehouse operations by lowering waste and energy consumption. They optimize resources and reduce the need for large gear, which benefits the environment and the bottom line.

In summary, warehouse management has an exciting future because of the combination of AI and drones. These technologies have the potential to revolutionize efficiency, safety, and environmental responsibility as they develop further. The work in this thesis contributes to the discussion by demonstrating the necessity of greater research in this area to find even more creative and environmentally friendly solutions for warehouses of the future.

References

Ali, S. S., Khan, S., Fatma, N., Ozel, C., & Hussain, A. (2023). Utilization of Drones in Achieving Various Applications in Smart Warehouse Management. *Benchmarking: An International Journal, 31*(3). https://doi.org/10.1108/bij-01-2023-0039

AlRushood, M. A., Rahbar, F., Selim, S. Z., & Dweiri, F. (2023). Accelerating Use of Drones and Robotics in Post-Pandemic Project Supply Chain. *Drones, 7*(5), 313. https://doi.org/10.3390/drones7050313

Atech Logistics. (2024, September 23). What Are The 4 Main Steps In Inventory Management? | Atech Logistics & Distribution. *Atech Logistics & Distribution.* https://www.atechlogistics.com/what-are-the-4-main-steps-in-inventory-management/

Atieh, A. M., Kaylani, H., Al-abdallat, Y., Qaderi, A., Ghoul, L., Jaradat, L., & Hdairis, I. (2016). Performance improvement of inventory management system processes by an automated warehouse management system. *Procedia CIRP, 41*(1), 568–572. https://doi.org/10.1016/j.procir.2015.12.122

Attaran, M. (2020). Digital technology enablers and their implications for supply chain management. *Supply Chain Forum: An International Journal, 21*(3), 1–15. https://doi.org/10.1080/16258312.2020.1751568

Becerra, P., Mula, J., & Sanchis, R. (2022). Sustainable inventory management in supply chains: Trends and further research. *Sustainability, 14*(5), 2613. https://doi.org/10.3390/su14052613

Blond. (2024, September 23). AI in Warehouse Management: Zooming in on the Benefits. *Requestum.com.* https://requestum.com/blog/ai-in-warehouse-management

BR Williams. (n.d.). 7 benefits of warehouse management systems. Retrieved from https://www.brwilliams.com/blog/7-benefits-of-warehouse-management-systems/

Business News Daily. (n.d.). Warehouse inventory management. Retrieved from https://www.businessnewsdaily.com/15869-warehouse-inventory-management.html

Chakraborty, A. (2022, November 19). What Is RFID Inventory Management? 2023 Comprehensive Guide. *Selecthub.* https://www.selecthub.com/inventory-management/rfid-inventory-management/

Cho, H., Kim, D., Park, J., Roh, K., & Hwang, W. (2018, June 1). 2D Barcode Detection using Images for Drone-assisted Inventory Management. *IEEE Xplore.* https://doi.org/10.1109/URAI.2018.8441834

Clarkston Consulting. (n.d.). Benefits of a warehouse management system. Retrieved from https://clarkstonconsulting.com/insights/benefits-of-a-warehouse-management-system/

Clarus WMS. (2023, March 14). WMS and TMS: Why You Need to Integrate! *Clarus WMS.* https://claruswms.co.uk/wms-tms-integration/

Conceição, J., De Souza, J., Gimenez Rossini, E., Risso, A., & Beluco, A. (2021). Implementation of inventory management in footwear industry. *Journal of Industrial Engineering and Management, 14*(2), 360. https://doi.org/10.3926/jiem.3223

Cyzerg. (n.d.). Warehouse digitalization: The future of warehousing. Retrieved from https://articles.cyzerg.com/warehouse-digitalization-the-future-of-warehousing/

DCL Corp. (n.d.). Automating inventory management. Retrieved from https://dclcorp.com/blog/inventory/automating-inventory-management/

Dekhne, A., Hastings, G., Murnane, J., & Neuhaus, F. (2019, April 24). Logistics automation: Big opportunity, bigger uncertainty. *McKinsey.* https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/automation-in-logistics-big-opportunity-bigger-uncertainty

Demirkıran, Y., & Ozturkoglu, O. (2022). Key Performance Measures and Digital-Era Technologies in Warehouses. *Operations and Supply Chain Management: An International Journal, 15*(2), 193–204. https://doi.org/10.31387/oscm0490340

Drissi Elbouzidi, A., Ait El Cadi, A., Pellerin, R., Lamouri, S., Tobon Valencia, E., & Bélanger, M. J. (2023). The role of AI in warehouse digital twins: Literature review. *Applied Sciences.* https://doi.org/10.3390/app13116746

Estrellas, L. (2024). Inventory Control: Definition, Types, & Methods. *SafetyCulture.* https://safetyculture.com/topics/inventory-management-system/inventory-control/

Fatima, Z., Tanveer, M. H., Waseemullah, Zardari, S., Naz, L. F., Khadim, H., Ahmed, N., & Tahir, M. (2022). Production plant and warehouse automation with IoT and Industry 5.0. *Applied Sciences, 12*(4), 2053. https://doi.org/10.3390/app12042053

France et al., & Kabir, A. (2024). *Thematic Analysis: A Practical Guide.* https://doi.org/10.58837/chula.ppj.39.8

Hans J Skovgaard. (2024). Mobile app development company | Cleveroad. *Cleveroad Inc. - Web and App Development Company.* https://www.cleveroad.com/

Hasan, M. K., Junjie, M., Ahasan Habib, A. K. M., Al Mamun, A., Ghazal, T. M., & Saeed, R. A. (2022a). IoT-based warehouse management system. *2022 International Conference on Cyber Resilience (ICCR)*, 1–6. https://doi.org/10.1109/ICCR56254.2022.9995768

Hasibuan, A. S. R., Wahyuda, W., & Sitania, F. D. (2021). Inventory management of 50 kg packaged cement products with a lot sizing ratio (case study: XYZ warehouse). *Teknika: Jurnal Sains Dan Teknologi, 17*(2), 235. https://doi.org/10.36055/tjst.v17i2.12684

Hayes, A. (2023, March 28). Inventory Management Defined, Plus Methods and Techniques. *Investopedia.* https://www.investopedia.com/terms/i/inventory-management.asp

Hopstack. (n.d.). Warehouse digital transformation. Retrieved from https://www.hopstack.io/blog/warehouse-digital-transformation

How does workflow automation reduce costs for manufacturing organizations? (2023, February 16). *Weever.* https://weeverapps.com/operational-excellence/automation-reduces-costs/

IBM. (n.d.). Inventory management. Retrieved from https://www.ibm.com/topics/inventory-management

Ingka Group. (2024, August 16). IKEA is elevating human - AI-powered drone collaboration. *Ingka Group*. https://www.ingka.com/newsroom/ikea-is-elevating-human-ai-powered-drone-collaboration/

Interlake Mecalux. (n.d.). Digital warehousing. Retrieved from https://www.interlakemecalux.com/blog/digital-warehousing

Inventrax. (n.d.). Impact of digital transformation on the warehouse. Retrieved from https://inventrax.com/blog/impact-of-digital-transformation-on-the-warehouse-2/

Ironpaper. (n.d.). Embracing the digital revolution in warehouse management: Key trends and impacts. Retrieved from https://www.ironpaper.com/webintel/embracing-the-digital-revolution-in-warehouse-management-key-trends-and-impacts

Jarašūnienė, A., Čižiūnienė, K., & Čereška, A. (2023). Research on Impact of IoT on Warehouse Management. *Sensors, 23*(4), 2213. https://doi.org/10.3390/s23042213

Jenkins, A. (2020, December 10). Warehouse Automation: The How, When & Why. *Oracle NetSuite*. https://www.netsuite.com/portal/resource/articles/inventory-management/warehouse-automation.shtml

Jenkins, A. (2023, July 10). 12 tips for warehouse layout efficiency. *Oracle NetSuite*. https://www.netsuite.com/portal/resource/articles/erp/warehouse-layout.shtml

Learn the key steps and metrics to evaluate the impact and value of warehouse automation for your operations. Find out how to calculate costs, benefits, and ROI. (2023, August 15). *Linkedin.com*. https://www.linkedin.com/advice/0/how-do-you-measure-roi-warehouse-automation

Lee, C. K. M., et al. (2018). Design and application of IoT-based warehouse management system for smart logistics. *International Journal of Production Research, 56*(8), 2753–2768. https://doi.org/10.1080/00207543.2017.1394592

Liu, K. Y. (2022). Warehouse and Inventory Management. *Supply Chain Analytics*, 219–269. https://doi.org/10.1007/978-3-030-92224-5_7

Lowry Solutions. (2014, September 19). The Difference between Warehouse Management Systems and Enterprise Resource Planning. *Lowry Solutions*. https://lowrysolutions.com/blog/the-difference-between-warehouse-management-systems-and-enterprise-resource-planning/

Maghazei, O., & Netland, T. (2019). Drones in manufacturing: exploring opportunities for research and practice. *Journal of Manufacturing Technology Management, ahead-of-print*(ahead-of-print). https://doi.org/10.1108/jmtm-03-2019-0099

Maghazei, O., & Steinmann, M. (2020). Drones in Railways. *Deleted Journal, 20*(3). https://doi.org/10.18757/ejtir.2020.20.3.4612

Malang, C., Charoenkwan, P., & Wudhikarn, R. (2023). Implementation and Critical Factors of Unmanned Aerial Vehicle (UAV) in Warehouse Management: A Systematic Literature Review. *Drones, 7*(2), 80. https://doi.org/10.3390/drones7020080

Marchuk, V. Y., & Harmash, O. M. (2020). Intellectualization of Logistics and Supply Chain Management. *Electronic Scientific Journal Intellectualization of Logistics and Supply Chain Management #1 2020*, 2. https://doi.org/10.46783/smart-scm/2020-2

Meloeny, S. (2022, December 27). Calsoft Systems. *Calsoft Systems | ERP, Network, IT Services*. https://www.calsoft.com/difference-between-wms-erp-software/

Minashkina, D. (2024). A review and research agenda for recent socially and environmentally sustainable practices for warehouse management systems. *The International Journal of Logistics Management, 35*(7), 60–98. https://doi.org/10.1108/ijlm-07-2023-0265

Minashkina. (n.d.). 16 Warehouse Automation Trends for 2024. *Www.cyngn.com*. https://www.cyngn.com/blog/16-warehouse-automation-trends-for-2024

Modula. (n.d.). Warehouse inventory management. Retrieved from https://modula.us/blog/warehouse-inventory-management/

Mordor Intelligence. (n.d.). Warehouse automation market report. Retrieved from https://www.mordorintelligence.com/industry-reports/warehouse-automation-market

Mostafa, N., Hamdy, W., & Elawady, H. (2020). An intelligent warehouse management system using the Internet of things. *The Egyptian International Journal of Engineering Sciences and Technology, 32*(1), 59–65. https://doi.org/10.21608/eijest.2020.42338.1009

Muha, R., Škerlič, S., & Erčulj, V. (2020). The Importance of Risk Management for the Introduction of Modern Warehouse Technologies. *Promet - Traffic&Transportation, 32*(3), 321–333. https://doi.org/10.7307/ptt.v32i3.3207

Munro, O. (2024, October 21). What Is Warehouse Automation? Examples, Benefits, & More. *Red Stag Fulfillment*. https://redstagfulfillment.com/warehouse-automation/

NetSuite. (n.d.). Warehouse management explained. Retrieved from https://www.netsuite.com/portal/resource/articles/erp/warehouse-management.shtml

Newcastle Systems. (n.d.). Disadvantages of automated warehouse robots. Retrieved from https://www.newcastlesys.com/blog/disadvantages-of-automated-warehouse-robots

Noyes, J., Booth, A., Moore, G., et al. (2019). Synthesizing quantitative and qualitative evidence to inform guidelines on complex interventions. *BMJ Global Health, 4*(1), e000893. https://doi.org/10.1136/bmjgh-2018-000893

Om, B., Modhe, K., Kulkarni, A., Londhe, A., & Chaitanya, S. V. (2023). Smart Surveillance Drone – Warehouse Operations. *International Journal of Advanced Research in Science, Communication and Technology*, 100–105. https://doi.org/10.48175/ijarsct-11618

Page, M. J., et al. (2021). The PRISMA 2020 statement: Updated Guideline for Reporting Systematic Reviews. *British Medical Journal, 372*(71). https://doi.org/10.1136/bmj.n71

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: an Updated Guideline for Reporting Systematic Reviews. *British Medical Journal, 372*(71). https://doi.org/10.1136/bmj.n71

Planergy. (n.d.). Inventory management techniques. Retrieved from https://planergy.com/blog/inventory-management-techniques/

Pramanik, P. K. D., Mukherjee, B., Pal, S., Upadhyaya, B. K., & Dutta, S. (2019). Ubiquitous Manufacturing in the Age of Industry 4.0: A State-of-the-Art Primer. *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, 73–112. https://doi.org/10.1007/978-3-030-14544-6_5

PRISMA. (2020). PRISMA. *Prisma-Statement.org.* http://www.prisma-statement.org/

ReadWrite. (n.d.). Warehouse automation helps with efficient inventory management. Retrieved from https://readwrite.com/warehouse-automation-helps-with-efficient-inventory-management/

Rejeb, A., Rejeb, K., Simske, S. J., & Treiblmaier, H. (2021). Drones for supply chain management and logistics: a review and research agenda. *International Journal of Logistics Research and Applications, 26*(6), 1–24. https://doi.org/10.1080/13675567.2021.1981273

SAP. (2024). What is a warehouse management system (WMS)? | SAP Insights. *SAP.* https://www.sap.com/products/scm/extended-warehouse-management/what-is-a-wms.html

Scopus. (n.d.). Accelerating use of drones and robotics in post-pandemic project supply chain. Retrieved from https://www.scopus.com/record/display.uri?eid=2-s2.0-85160278370

Scopus. (n.d.). Applications of Industry 4.0 Technologies in Warehouse Management. Retrieved from https://www.scopus.com/record/display.uri?eid=2-s2.0-85163605788

Scopus. (n.d.). Drone transportation system: Systematic review of security dynamics for smart mobility. Retrieved from https://www.scopus.com/record/display.uri?eid=2-s2.0-85153338670

Scopus. (n.d.). Drones for supply chain management and logistics: A review and research agenda. Retrieved from https://www.scopus.com/record/display.uri?eid=2-s2.0-85115602822

Scopus. (n.d.). Intelligent scheduling algorithms for enhancement of drone-based logistic supply chain systems. Retrieved from https://www.scopus.com/record/display.uri?eid=2-s2.0-85171532100

Scopus. (n.d.). Joint optimization of customer location clustering and drone-based routing for last-mile deliveries. Retrieved from https://www.scopus.com/record/display.uri?eid=2-s2.0-85080981723

Shanmugapriya, M. K., Sri, D., Fareeth, M., Rila, M., & Kumar, M. (2023). *Warehouse management and inventory control.* International Scientific Journal of Engineering and Management. https://doi.org/10.55041/ISJEM00217

ShipHero. (n.d.). Inventory control and warehouse automation explained. Retrieved from https://shiphero.com/blog/article/inventory-control-and-warehouse-automation-explained/

Sortly. (n.d.). What are the 3 major inventory management techniques? Retrieved from https://www.sortly.com/blog/what-are-the-3-major-inventory-management-techniques/

TechTarget. (n.d.). 8 benefits of a warehouse management system. Retrieved from https://www.techtarget.com/searcherp/feature/8-benefits-of-a-warehouse-management-system

TechTarget. (n.d.). Warehouse management system (WMS). Retrieved from https://www.techtarget.com/searcherp/definition/warehouse-management-system-WMS

Tikwayo, L. N., & Mathaba, T. N. D. (2023). Applications of Industry 4.0 Technologies in Warehouse Management: A Systematic Literature Review. *Logistics, 7*(2), 24. https://doi.org/10.3390/logistics7020024

Tubis, A. A., & Rohman, J. (2023). Intelligent Warehouse in Industry 4.0—Systematic Literature Review. *Sensors, 23*(8), 4105. https://doi.org/10.3390/s23084105

Unleashed Software. (n.d.). Inventory management guide. Retrieved from https://www.unleashedsoftware.com/inventory-management-guide

Vardells. (n.d.). 6 key benefits of a warehouse management system. Retrieved from https://www.vardells.co.uk/blog/6-key-benefits-warehouse-management-system/

Wahab, S. N., Khoo, H. A., Sundram, V. P. K., & Annas, M. (2023). Green Warehouse Practice: Critical issues in drone technology adoption. *Environment-Behaviour Proceedings Journal, 8*(23), 217–222. https://doi.org/10.21834/ebpj.v8i23.4441

Ware2Go. (n.d.). Digital warehousing. Retrieved from https://ware2go.co/articles/digital-warehousing/

Warehouse automation: What is it, how it works, today's trends. (2023). *SAP.* https://www.sap.com/india/products/scm/extended-warehouse-management/warehouse-automation.html

Yourshortlist. (n.d.). 7 benefits of using a warehouse management system. Retrieved from https://yourshortlist.com/7-benefits-of-using-a-warehouse-management-system/

ESSAY	Authors	Title	Year	Methods Used	FINDING
1	*Lihle N. Tikwayo *Tebello N. D. Mathaba *	Applications of Industry 4.0 Technologies in Warehouse Management: A Systematic Literature Review	2023	systematic literature review methodology	Improved process efficiency is a key benefit of Industry 4.0 technologies.Real-time data availability enhances decision-making in warehouse management.Competitive advantage is gained through digital integration of business activities.High life cycle cost is a prominent barrier to implementation.Inadequate resources and security risks hinder technology adoption.Future research is needed on cloud computing and augmented reality.
2	Karamitsos G.; Bechtsis D.; Tsolakis N.; Vlachos D.	Unmanned aerial vehicles for inventory listing	2021	development and implementation	Drones enable real-time, accurate inventory listing in warehouses.They minimize operational costs for supply chain stakeholders.Drones reduce human injury risks in facilities.The system allows 24/7 drone operation for inventory listing.An emulation tool assesses drone operations in warehouses.The research includes a taxonomy of UAV characteristics.They utilize rechargeable, environmentally-friendly batteries.
3	Castro D.G.; Garcia E.V.	Safety Challenges for Integrating U-Space in Urban Environments	2021	qualitative and quantitative	The U-space framework is not mature enough for current challenges.Safety assessment methodologies need iterative approaches for critical services.Resilience engineering techniques can mitigate risks in autonomous systems.The European drone market is projected to grow significantly by 2050. Standardization efforts are necessary for U-space service development.Safety challenges arise from integrating U-space in urban scenarios.Safety metrics and operational insights are essential for urban environments.
4	Rajalingam S.; Kanagamalliga S.; Sakthi Priya K.; Karuppiah N.	Optimizing Drone delivery: An efficient design for shipper applications	2024	system design	Drones enhance package delivery efficiency and accuracy.GPS technology is crucial for tracking package locations.Facial recognition verifies package delivery to consumers.Intelligent control methods improve drone delivery performance.Comparison of delivery methods shows drones' advantages in various fields.Advanced features improve the proposed drone delivery model.

5	Banjar A.; Jemmali M.; Melhim L.K.B.; Boulila W.; Ladhari T.; Sarhan A.Y.	Intelligent Scheduling Algorithms for the Enhancement of Drone-Based Innovative Logistic Supply Chain Systems	2023	computational experiments and algorithm optimization	The MID algorithm achieved a success rate of 87.7%.Average gap for MID algorithm was 0.001.Execution time for MID algorithm was 0.0215 seconds.Algorithms were tested on 1520 unique instances.IRR algorithm had a success rate of 70.5%.Research highlighted drone logistics' potential in disaster response.
6	Abderahman Rejeb, Karim Rejeb, S. Simske, Horst Treiblmaier	Drones for supply chain management and logistics: a review and research agenda	2021	Systematic Literature Review.	Drones support humanitarian logistics and improve delivery efficiency.They reduce costs and enhance flexibility in supply chains.Drones increase sustainability by lowering carbon emissions.Regulatory issues hinder widespread drone adoption in logistics.Research gaps exist in drone impact on performance and customer satisfaction.Technical challenges include limited payload and battery life.
7	AlRushood M.A.; Rahbar F.; Selim S.Z.; Dweiri F.	Accelerating Use of Drones and Robotics in Post-Pandemic Project Supply Chain	2023	statistical modeling, case studies, and literature reviews.	Drones enhance productivity and reduce costs in construction projects.Supply chain management benefits from drones and AI integration.Drones improve inventory accuracy and real-time visibility.Drones minimize human intervention in remote construction sites.Safety inspections are more effective with drone technology.
8	S. Ajakwe, Dong-Seong Kim, Jae Min Lee	Drone Transportation System: Systematic Review of Security Dynamics for Smart Mobility	2023	PRISMA-SPIDER Methodology	The study identifies security risks in drone transportation systems (DTS).It highlights increasing violations despite security technology advancements.The review examines AI model proposals versus actual implementations. The research emphasizes the need for improved cybersecurity measures. Drones improve inventory management in smart warehouses.
9	Sadia Samar Ali, Shahbaz Khan, Nosheen Fatma, Cenap Ozel, Aftab Hussain	Utilisation of drones in achieving various applications in smart warehouse management	2023	Mixed-Method Approach combining Fuzzy Delphi Method, Graph Theory Matrix Approach (GTMA), and Logistic	Drones improve inventory management in smart warehouses.Intra-logistics is a significant application of drones.Inspections and surveillance are enhanced by drone usage.Operational effectiveness is a key enabler for drone adoption.Compatibility of drone integration impacts adoption significantly.Quality and value offered are crucial for adoption.Nine enablers for drone adoption in warehouses were identified.Logistic regression analysis aids warehouse managers in drone adoption.

				Regression Analysis	
10	Srinivas Reddy Edulakan ti a, Sanjeev Ga nguly b	T1 - Review article: The emerging drone technology and the advancement of the Indian drone business industry	2023	Systematic Literature Review (SLR)	The drone industry is experiencing explosive global growth.India has potential to become a global drone hub.Government initiatives support drone technology adoption in India.Demand for drones is surging across various industries. Key drivers include technological advancements and consumer interest.The market is expected to grow at 13.62% CAGR.
11	Malik Doole, Joo st Ellerbroek, Ja cco Hoekstra	T1 - Estimation of traffic density from drone-based delivery in very low level urban airspace	2020	Traffic Demand Estimation Framework combined with a Case Study Approach	Drone delivery could exceed 63,596 daily operations in Paris by 2035.Traffic density surpasses current global commercial aircraft traffic by six-fold.Framework established for estimating drone delivery traffic in five countries.High-density drone traffic presents challenges for U-Space management.Fast-food delivery via drones is feasible in urban areas.
12	Wen-Chyuan Chiang, Yuyu Li, J. Shang, Timothy L. Urban	Impact of drone delivery on sustainability and cost: Realizing the UAV potential through vehicle routing optimization	2019	Mixed-Integer Linear Programmin g (MILP) Green Routing Model	The model minimizes carbon emissions and delivery costs.UAVs reduce fuel costs and pollutant emissions.Genetic algorithm efficiently solves the complex routing model. Routing costs decrease with reduced vehicle gross weight.UAVs enhance sustainability in last-mile deliveries.
13	Salama M.; Srinivas S.	Joint optimization of customer location clustering and drone-based routing for last-mile deliveries	2020	Mathematic al Programmin g Model	The integration of drones improves delivery efficiency and reduces costs.Mathematical models optimize drone and truck delivery decisions.Unrestricted focal points enhance delivery performance with fewer locations. Delivery completion time is influenced by drone speed and quantity.Clustering delivery locations optimizes truck and drone operations.Multiple drones per truck significantly lower operational costs.

14	Silvia Proia; Graziana Cavone; Antonio Camposeo; Fabio Ceglie; Raffaele Carli; Mariagrazia Dotoli	Safe and Ergonomic Human-Drone Interaction in Warehouses	2022	Speed and Separation Monitoring (SSM) Methodology , Rapid Upper Limb Assessment (RULA), Artificial Potential Field (APF) Technique, and Control Algorithms such as Linear Quadratic Regulator (LQR) and Iterative LQR (iLQR)	The methodology improves operator safety and well-being.Efficiency and production costs are significantly reduced.Speed and separation monitoring is applied to human-drone interaction.Quadrotor successfully performs pick and place tasks.Collision avoidance with warehouse shelves is achieved.Ergonomic posture is evaluated during drone interaction.The proposed method proves effective for safe HDI.
15	Environment-behaviour proceedings journal	Green Warehouse Practice: Critical issues in drone technology adoption	2023	primarily qualitative	Drones revolutionize warehouse operations and inventory management.They are portable and highly maneuverable for various tasks.Indoor and outdoor flight capabilities enhance operational efficiency.The study identifies issues faced by warehouse operators.There is a need for more scholarly studies on drone adoption.
16	M. Nurullah Turgut, Bilal Şeker	An exploratory study on the use of unmanned aerial vehicles (UAVs) in transportation: drone transportation and its applications	2022	Active Learning Techniques	Drone transportation is rapidly increasing in logistics enterprises.Limited studies exist on drone transportation in recent literature.UAVs are adapting quickly from military to commercial applications. Drone transportation will significantly grow by 2030.Businesses prefer drones for efficient customer demand responses.
17	Jakub Kraus, Adam Kleczatský, Šárka Hulínská	Social, technological, and systemic issues of spreading the use of drones	2020	qualitative research methods	The paper identifies obstacles to drone usage expansion.Three issue groups are defined: social, technological, and systemic.Stakeholder attitudes influence drone development and acceptance. Eliminating identified issues could enhance drone usage.

18	Yi Wu, Jian Liu, Phuc Nguyen	DroneChase: A Mobile and Automated Cross-Modality System for Continuous Drone Tracking	2023	experimental research methods	DroneChase tracks drones in line-of-sight and non-line-of-sight conditions.The system integrates acoustic and visual signals for tracking.It operates effectively under blockage conditions.It performs reliably in both day and night conditions. Utilizes Raspberry Pi for real-time monitoring and detection.The system is mobile and portable for continuous tracking. Employs six microphones for enhanced audio capture quality.Achieves high precision in drone localization using YOLOv5.Implements a student-teacher framework for self-supervised learning.
19	Gabriel Râzvan Radu Boboc Albert Godina Dimitris Smalcerz Mourtzis Franklin Salazar María Sofía Martínez-García Angel De Castro Carl Cháve-Fuentes María Cazorla	UAVs for Business Adoptions in Smart City Environments: Inventory Management System	2023	combination of literature review and experimental research	UAVs enhance inventory management in smart city environments.SCADA system developed for DHL's inventory management using drones.Infrared technology verifies merchandise availability efficiently.UAVs reduce waiting times for product availability information. OPC communication protocols facilitate virtual and real environment integration.
20	Mr. Om Bayas Mr. Kshitij Modhe Mr. Kulkarni Mr. Londhe S. Chaitanya	Smart Surveillance Drone – Warehouse Operations	2023	Experimental/System Evaluation	Drones enhance efficiency in warehouse operations through automation.They facilitate inventory management and stock inspection tasks.Drones provide visual feedback and live video feeds. Drones reduce reliance on human operators in warehouses.They assist in intralogistics, transferring parts efficiently.Advances in AI improve drone capabilities for warehouse tasks.Drones are increasingly adopted due to e-commerce growth.Save