Vol. 08, No. 2 (2026) 1191-1202, doi: 10.24874/PES08.02B.009

Proceedings on Engineering Sciences

www.pesjournal.net

UTILIZING THE INTERNET OF THINGS (IOT) TO STREAMLINE WAREHOUSING AND LOGISTICS PROCESSES

Ginnel Quadrasa
Princy Randhawa[1]
Jitendra Kumar Jaiswal
Ramakrishna Garine
Nikhil Kassetty
Nithesh Naik

Received 19.01.2026.
Revised 16.04.2026.
Accepted 30.04.2026.

Keywords:

Supply chain management, Internet of Things (IoT), Logistics operations, Smart logistics, Smart warehousing

A B S T R A C T

The incorporation of the Internet of Things (IoT) into logistics and warehousing has entered into a new era of enhanced efficiency, transparency, and optimization. Real-time data gathering and quality have become crucial in addressing the complexity of client orders due to the development of high-speed networks and smart devices. This paper presents a novel IoT-based architecture designed to enhance efficiency and optimize operations within warehouse and logistics management. The study addresses the problem of traditional manual processes being unable to manage the complexity and volume of modern logistics tasks. In warehouses, technologies like RFID and Wireless Sensor Networks are employed to maintain precise inventory levels, thereby avoiding issues of stockouts or excess stock. Despite various Warehouse Management Systems (WMS) and automation techniques discussed in existing literature, many focused narrowly on specific warehouse areas and often fail in comprehensive deployment. Our proposed IoT-based architecture addresses these shortcomings by segmenting the warehouse into multiple domains to ensure proper management. We introduced a Warehouse IoT Efficiency Index (WIEI) to benchmark operational impact, detailed a modular MQTT-driven architecture comprising sender, receiver, broker, and database components mapped to WMS functions, and provided a quantitative comparative analysis framework along with a data-flow model to guide end-to-end deployment and evaluation.

© 2026 Published by Faculty of Engineering

1. INTRODUCTION

IoT has acquired broader appeal and recognition in warehousing and logistics operations thanks to the developing applications of high-speed networks and smart devices. Due to the criticality and variety of customer orders, real-time data and information quality are progressively growing (De Vass et al., 2018). The Industrial Revolution's widespread production of consumables has increased the demand for modern warehouses and smart logistics (Ackerman, 1990; Al-hamadani & Al-Darraji, 2025). With more items needing

[1] Corresponding author: Princy Randhawa
Email: Princy-aiml@dsu.edu.in

to be handled, warehousing and logistics have become more unpredictable, so traditional and manual techniques are no longer compatible for handling such a huge volume of activities. To address these issues, modern innovation must be used (Staudt et al., 2015). Logistics management's primary responsibility is to maintain complete synchronization of logistics tasks, participants, and stakeholders and deliver the required goods to the right clients at the appropriate time and location and in the correct condition (Pienaar & Vogt, 2012). Ensuring sales and customer satisfaction is the primary purpose of a warehouse (Tang et al., 2018). Order picking can comprise about 50-55% of the entire operating cost for the warehouse. As a result, it highlights the issue that traditional manual operation has a negative impact on warehouse operating efficiency and is no longer responsive to consumer needs (Frazelle, 2002).

IoT is a group of technologies that allows for identifying necessary items and performing daily tasks utilizing cell phones, computers, GPS, and other devices (Lopes & Moori, 2021). The idea behind IoT is the seamless data collection and interchange made possible by the interconnection of common objects and gadgets. Additionally, such integration makes it possible for things to become intelligent objects that can converse and take universally applicable judgements. To acquire end-to-end traceability and visibility, the logistics systems in this vision can make use of such pervasive connectivity, which subsequently increases the effectiveness of logistical operations (Tadejko, 2015). IoT in logistics and warehousing has entered a new era of effectiveness, openness, and optimisation. Moreover, the ability of the IoT-supported system to provide real-time and useful data about the logistics process can be used to boost operational effectiveness in terms of channel and traffic management, inventory regulation, asset utilization, security, and safety. The application of IoT may remarkably enhance the scope of logistics systems in terms of observing, controlling, managing, and optimising logistics activities, according to a thorough study undertaken by both a logistics service provider (DHL[2]) and an IoT technology specialist (CISCO1) (Macaulay & Buckaew, 2015). IoT also facilitates responsibility and administrative workload management, making it simpler to monitor and manage a data warehouse (Jin et al., 2013).

The shipments and logistics assets can be traced and tracked in real-time using GPS systems and RFID, and the WSNs, which have real-time sensing capabilities along shipping trajectories, ensure the enhancement of logistics shipments in any harsh environmental situations (Tejesh & Neeraja, 2018). IoT can be applied to warehouse management to track products, predict demand trends, manage and operate inventory, and perform other real-time warehouse functions (Jarašūnienė et al., 2023), as shown in Table 1.

Table 1. Primary IoT Technologies

Name of the Technology	Inbound Applications	Outbound Applications
RFID QR Code Barcode WSN EDI GPS Sensor	Placement Count of Cycles Goods' Location Management of Receipts Total Physical Count Optimization of Storage Workforce Optimization Humidity and Temperature Control Control of Material flow Streamline Inventory Demand and Sales Forecasting	Order acceptance from host systems Packing list Dispatch Prioritization of orders Transportation End User services
Zigbee Z-wave MQTT Bluetooth WI-FI NFC WSN Middleware Cloud Computing	Streamline information exchange Integration and collaboration with packages under warehouse management system	

Customers want their items to be delivered safely, quickly and with little to no expense. The inline innovations enhance productivity along with consumer happiness while dealing with more intense rivalry. If a certain logistics company doesn't improve present logistical systems, it risks going out of business (Lee & Lee, 2015). An effective way to stay current with new developments is to construct smarter logistics based on new technology (Haller et al., 2009). Undoubtedly, IoT is going to be crucial to the implementation of smart logistics (Hamdy et al., 2018; Tran-Dang et al., 2022), which fundamentally alters the architecture of the logistics system and the logistics operation mode. Implementing these fundamental technologies continues to be a major problem because there is still a dearth of knowledge about how organisations can make use of this potential and adopt these technologies (Ding et al., 2021). To develop IoT-based smart logistics and warehousing into a reality, multiple issues still need to be taken into account, including applicable scenarios, inline difficulties, and future directions (Ashton, 2009). Existing work focuses on isolated sub-processes (e.g., RFID-based picking or GPS tracking), but holistic frameworks that integrate multiple modules with measurable KPIs remain limited. This paper contributes by:

- Proposing a WIEI to benchmark IoT-enabled efficiency.
- Designing of a modular MQTT-based architecture for event-driven WMS operations

- Providing a traditional vs IoT comparative framework.
- Presenting a data-flow diagram (DFD) for replication.

2. KNOWLEDGE OF BACKGROUND FOR LOGISTICS

Smart and inline logistics are defined as a logistics system that can enhance flexibility, permit better adaptation to market challenges and changes, and incorporate a business closer to its client's needs (Witkowski, 2017). By adopting cutting-edge communications and information technologies, smart logistics could be integrated and optimized towards the logistics system through thorough analysis, prompt processing, and self-adjustment. There are four distinct stages that delineate this evolution of logistics, each of which is characterized by technological innovations and changes. These stages are inextricably linked to technological advancements. Mechanical equipment was introduced during this period and took the place of manual labor, such as the first truck tractor produced by the CLARK Equipment Company in 1917 (Chung, 2021). The establishment of internal combustion engines and manufacturing of mechanical utilities led to the emergence of logistics mechanization in the 1920s. The development of sensors, barcodes, and RFID technology in the 1960s marked the beginning of logistics automation (Ashton, 2009). Information technology, networks, and e-commerce contributed a crucial role in the logistics integration of the 1990s to the 2000s (Barreto et al., 2017; Gustin et al., 1995; Song et al., 2020). Internet connectivity allowed for the expansion of business transactions to an industry level, as shown in Figure 1.

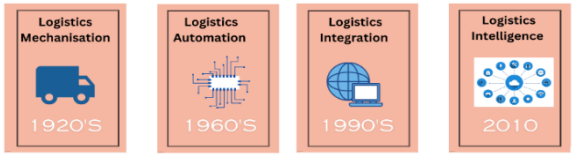


Figure 1. Timeline of the Evolution of Logistics

The AI, IoT, and big data propelled logistics intelligence in the twenty-first century (Ashton, 2009). Smart logistics improves efficiency, accuracy, and dependability in logistics operations like parcel sorting and real-time tracking by incorporating cloud manufacturing, IoT, mobile robotics, and other cutting-edge concepts (Lancioni et al., 2000; Williams et al., 1997). Through improved decision-making for logistics operations like automatic process control and product flow management, the logistics paradigm's overall efficiency is significantly increased.

Seven key scenarios that are essential for effective operations by smart logistics are explained as the following and further summarized in Table 2:

1. Transportation: One of the most crucial economic activities in logistics is the movement of goods between locations (Leung et al., 2000).
2. Storage: The logistics supply chain includes inventory control and management as a key component (Shin et al., 2013).
3. Loading and unloading: It is the process of moving goods, whether manually or automatically (Kim et al., 2015).
4. Packaging: Products are packaged to help with storage and transportation as well as to protect them during distribution (Tseng et al., 2005).
5. Processing for distribution: Includes activities like packaging, sorting, and labelling to satisfy requirements (Lee & Lee, 2015).
6. Distribution: Delivery of goods in accordance with customer order specifications, with a significant impact on logistics costs (Brockman, 1999).
7. Information processing: For more effective logistics planning and execution, information processing involves gathering and processing dynamic information (Alho et al., 2014).

Table 2. Key Scenarios for Smart Logistics

Scenario	Description
Transportation	Transporting things from one place to another is a core logistical economic activity.
Storage	Logistics supply chain inventory management and control.
Loading and unloading	Procedure for transferring products, either automatically or manually.
Packaging	Products' preparation for distribution, transit, and storage.
Processing for Distribution	Tasks such as labeling, sorting, and packaging to comply with specifications.
Distribution	The timely delivery of goods in accordance with client criteria.
Information Processing	Obtaining and analyzing dynamic data to enable efficient logistics planning and implementation

3. IOT INTEGRATION IN LOGISTICS

The core tenet of the Internet of Things (IoT) is that different objects can communicate with one another and work together with their neighbours (Jianyu et al., 2015; Lancioni & Chandran, 1990; Karrieva et al., 2026). This helps to accomplish the main objective of giving a computer the ability to understand information without the assistance of a human through special addressing schemes (Bardi et al., 1994). The smart and inline logistics system can acquire information about cargo, transportation routes, logistics vehicles, warehousing, and so on at any point in time and from any location by using sensors, RFID tags, actuators, mobile phones, and so on, as shown in Figure 2. It can also acquire end-to-end interconnection for information exchange and communication via network technology. Observing the

actual conditions of shipments and products is crucial in logistics, especially for sensitive products exposed to environmental conditions. IoT-based solutions can be established to trace and track the conditions of food products and then suggest informed decisions on product management and control (Dorsemaine et al., 2015). The quality of logistics operations is largely dependent on the results of decision-making. IoT will be crucial as a data-driven technology to enhance decision-making through effective data acquiring, processing, and analysis. Intelligent systems that use sensing and communication technologies monitor the ambient environment and product states in real time, allowing for informed control (Uckelmann et al., 2011).

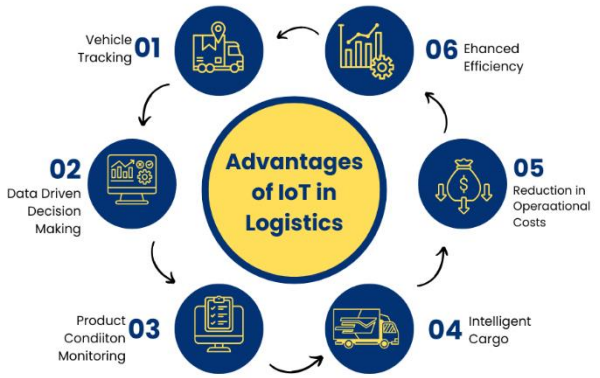


Figure 2. Advantages of the Implementation of IoT in Logistics

A vehicle tracing and tracking system is designed and developed to trace and track the position of any equipped vehicle at any time and from any location, using inline technologies such as the GPS to acquire geographic coordinates at regular time intervals and the global system for mobile communication or general packet radio service (GSM/GPRS) to transmit and update the vehicle's location in a database (Giusto et al., 2010). Different technologies such as GIS, RFID, 3G communication, middleware technology, and AI are applied in the cargo tracking system to achieve real-time streamlined cargo tracking via data communication, signal acquisition, and information processing (Accorsi et al., 2017). An IoT-equipped supply chain for perishable food allows for the acquisition of real-time and inline shipment information (Pal & Kant, 2018). The iCargo project aims to create intelligent cargo with a variety of functions such as self-analysis and identification, status monitoring, context detection, and decision-making based on autonomous registrations (Lee et al., 2014). By incorporating the inline technologies, logistics assets could be transformed into smart objects that can sense their surroundings and transmit a signal to nearby smart objects to collect IoT data (Zhang et al., 2017). As the cellular communication technology has been acquiring an international standard and sustainable technology, equipping it with important logistics assets (e.g., cargos such as trucks, trailers, and ships) can minimize the operation costs in the long run (Meyer et al., 2009; Sternberg et al., 2010).

4. FOUNDATION OF EFFICIENT WAREHOUSING

IoT technology can enhance the optimization and management of various activities throughout the entire supply chain. These activities include: (1) providing real-time and inline visibility of the inventory; (2) allowing remote monitoring of goods; (3) tracking and tracing the status of compartments, pallets, or deliveries; (4) managing shipping schedules; (5) overseeing reception and storage operations; (6) coordinating staff-orientated activities; and (7) ensuring warehouse security and authenticity.

The Warehouse Management System (WMS) oversees and manages the entire system in coordination with the management department as shown in Figure 3.

4.1 Analytical Model for IoT Impact

Total warehouse operating cost as in eq. 1:

$$C_{base} = C_{order} + C_{storage} + C_{transport} + C_{damage} + C_{energy} \quad (1)$$

where,
C_{base} = Baseline (traditional) warehouse operating cost. C_{order} = Cost of order picking (labor + errors)
$C_{storage}$ = Inventory holding cost (space, utilities)
$C_{transport}$ = Transportation cost (fuel, vehicle ops)
C_{damage} = Losses from shrinkage, damage, and misplacement.
C_{energy} = Energy consumption cost (lighting, forklifts)

With IoT, costs become as in eq. 2:

$$C_{IoT} = \sum(C_i(1-\alpha_i)) + \frac{C_{CapEx}}{T} + C_{OpEx} \quad (2)$$

where,
α_i=Reduction factor (0–1) due to IoT for each cost
C_{CapEx}= Capital expenditure on IoT infrastructure.
C_{OpEx}= Operating expenditure for IoT (maintenance, licenses)
T = Useful life of IoT investment (years)

The net saving in eq. 3:

$$\Delta C = C_{base} - C_{IoT} \quad (3)$$

The operational efficiency of a warehouse hinges on a series of pivotal processes, each playing a crucial role in enhancing productivity as mentioned in Figure 4 (Kiritsis, 2011), they are as follows and shown in eq. 4:

Warehouse IoT Efficiency Index (WIEI):
The WIEI is a composite Key Performance Indicator (KPI) designed to benchmark the operational impact of IoT integration by weighing service quality and visibility against total operating costs. It is defined as:

$$WIEI = \frac{OTIF+INV_{acc}+RT_{track}}{C_{oper}} \quad (4)$$

where,

$OTIF$= On-Time-In-Full, represents the delivery rate (%). This justifies the "service quality" aspect of the index, as higher IoT-enabled coordination (like GPS and RFID) directly increases the ability to meet customer demands accurately and promptly.

INV_{acc}= inventory accuracy, represents the accuracy of stock levels (%). This justifies the "transparency" aspect, as technologies like RFID and WSNs eliminate manual counting errors.

RT_{track}= real-time tracking capability (binary / score), a binary or scored value representing the presence and effectiveness of live tracking capabilities. This justifies the "intelligence" of the system

C_{oper} = operating cost, represents the total cost to run the warehouse, including order picking, storage, transport, and energy



Figure 3. Architecture of WMS (Context Diagram)

This gives a measurable KPI to compare pre- and post-IoT scenarios.

It begins with the receipt phase, a foundational stage in which the goal is to ensure that the correct number of items arrives on time. RFID tags, which are well-known for their accuracy, prove to be important aids in this attempt. They precisely document the arrival of items, and when coupled with automated scanners, they can capture the weight and dimensions of incoming shipments. This detailed data serves as the foundation for choosing the best storage location, effectively improving the reception process by accelerating dock unloading and optimizing warehouse space utilization.

Following receipt is the "Put-away" stage, where items are transferred from the reception dock to their designated storage locations. Mobile and wearable devices are involved in this phase, ensuring that items are accurately placed, thereby maintaining a well-organized inventory system. The adoption of smart forklifts, equipped with advanced sensors, marks a substantial improvement in IoT applications within the warehouse. These forklifts not only minimize the risk of accidents but also reduce the time required to complete tasks, contributing to an efficient storage optimization process.

The "Assembly and Shipping" stage is critical for warehouse operations, involving the shipping and handling of consumer orders. High efficiency in this stage is crucial as errors can diminish customer satisfaction. Wireless wearables improve this process by enabling real-time and inline scanning throughout the warehouse. Smart forklifts equipped with scanners and sensors provide updates on deliveries and ensure safe handling of products. Moreover, a trailer tracker system utilizing GPS technology tracks the current location of shipments, enhancing the monitoring and coordination of deliveries.

All the above information is stored in an information management system; various departments interact and function both collaboratively and independently, as shown in Figure 4. Each department has specific tasks that are performed in conjunction with others, facilitated by designated interfaces. The functional view, illustrated in Figure 5, represents the most fundamental model of an information system. It details the interfaces, functional elements, connectors, and both internal and external entities of the system. This view not only clarifies the functions of each element but also sets the scope and interaction of each entity within the system. The interfaces, comprising both hardware and software components, are depicted through large blocks representing functional elements, with arrows indicating the connections between them.

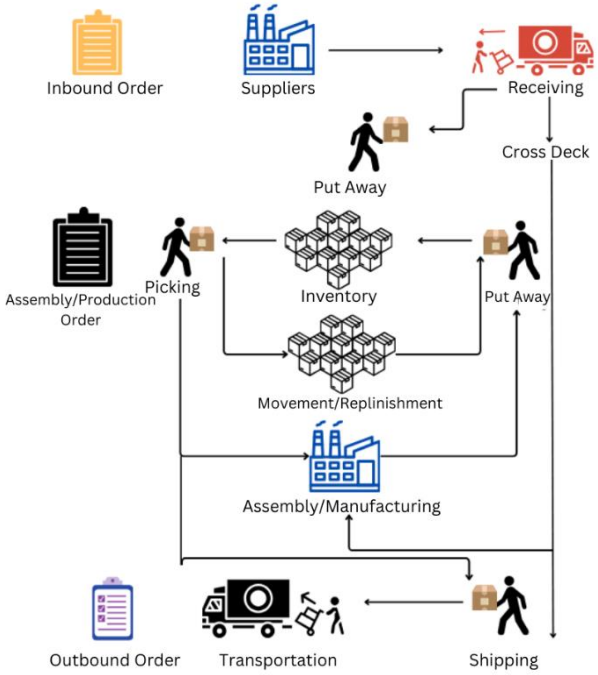


Figure 4. An Efficient process of Warehouse Inventory Flow

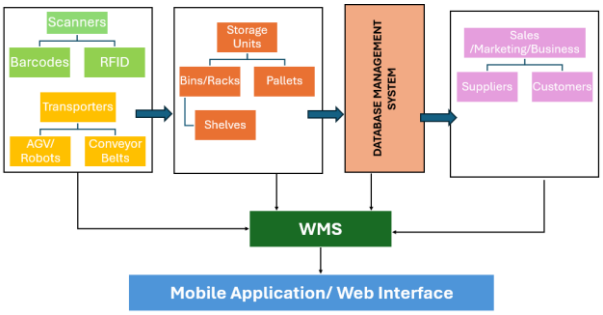


Figure 5. Functional Diagram of Warehouse Management

By integrating these processes and technologies, a warehouse can significantly enhance its operational efficiency, from the initial receipt of goods to their final shipment, all while maintaining high levels of safety and accuracy.

5. ARCHITECTURE OF THE WAREHOUSE MANAGEMENT

In this section, we describe the prototype in implementing the architecture of a smart warehouse using IoT technologies. It is divided into four modules as follows and in Figure 6(a) and (b):

Sender Module: This module functions as the primary data collection point in the warehouse and uses scanners to read barcodes and RFID tags on items. It accurately tracks the movement and status of goods such as whether they are being received, stored, or dispatched. The core technology used in this module is the ESP32, a compact microcontroller to process the capabilities in connectivity, including Wi-Fi and wired connections. This device is embedded in handheld scanners and enables mobile tracking and data capture throughout the warehouse.

Receiver Module: Serving as the informational output for the warehouse operations, this module displays critical data on goods movements. It provides real-time updates and status reports, facilitating efficient management of incoming and outgoing goods.

Communication Protocols: This component establishes a continuous network of communication between various IoT devices within the warehouse. Using a Raspberry Pi as a central hub, it acts as a broker managing the data flow between multiple senders and receivers. This setup ensures rapid and reliable exchange of information across the warehouse, essential to maintain continuous operations without physical connectivity constraints.

Database: It will act as the repository of all transactional data; this module records every detail concerning the items managed within the warehouse. It logs entries on item arrivals, storage locations, and dispatch times, thus serving as a complete historical record that supports both immediate operational needs and long-term analytics.

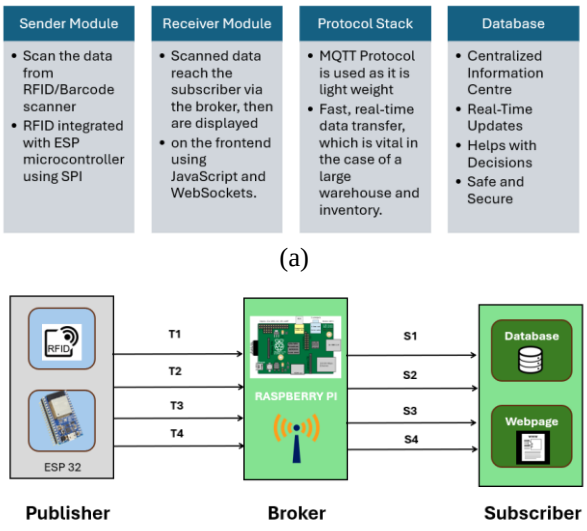


Figure 6. (a) Design of the prototype (b) MQTT Architecture of the IoT

6. IOT INNOVATIONS' BENEFITS IN WAREHOUSE MANAGEMENT

The IoT application in warehousing goes beyond efficiency improvements. One of the ground-breaking developments in this area is the use of zigbee wireless network technology to integrate an automated logistics control system for automated storage and retrieval systems (as/rs) (Mehmood et al., 2016). This solution employs a star control structure, which adeptly addresses users' variable control requirements (Harrison et al., 2004). It improves the intelligence, simplicity, and overall efficacy of a 3D warehouse logistics control system by doing so. These cutting-edge systems actively contribute to increased operational efficiency while considerably shortening the time required for various material handling procedures. Another notable advancement is the adoption of intelligent warehouse measurement and control systems based on Zigbee wireless sensor network (WSN) technology and network nodes, as shown in Figure 7. The use of Zigbee technology for environmental management and warehouse control in this design elevates warehouse management to a new degree of intelligence which enables real-time visibility and control over numerous warehouse activities, resulting in more efficient and intelligent warehouse operations.

RFID-based intelligent warehouse management systems also make use of IoT technology to improve inventory control and operational efficiency. These solutions verify that products are always on the right track at the right time by making the most of existing equipment and facilities, improving not only inventory management but also streamlining operations for enhanced overall warehouse efficiency (Ma, 2016). Furthermore, the development of IoT-based solutions has shown to be a reliable alternative for more effective distribution centre

management. These systems provide complete visibility by ubiquitously connecting inventories, allowing for the optimization of various logistics processes (Liu et al., 2010). This increased visibility and connectivity has a cascade effect, streamlining distribution centre operations and leading to increased efficiency and lower operational expenses (Li et al., 2011).

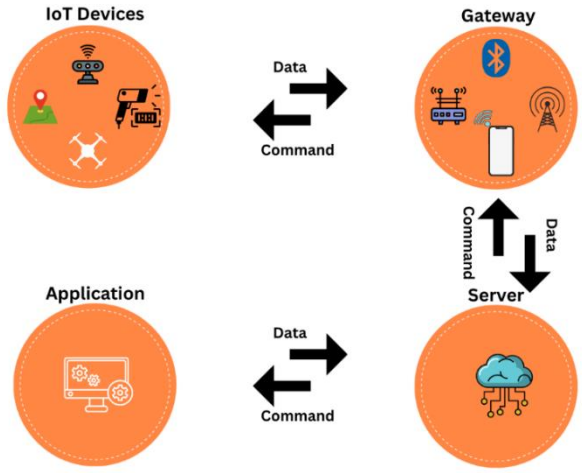


Figure 7. The process of application of IoT in Warehouse Management

Real-time locating systems (RTLS), as demonstrated by technologies like "ilocate," have revolutionized asset management in interior spaces even further. These systems use active rfid technology to trace and track, visualize, and localizing things in the warehouse in real-time. These technologies significantly help to improve warehouse safety and efficiency by offering accurate and real-time asset management and monitoring (Lou et al., 2011). To improve inventory control and material handling, large-scale warehouse testbeds such as "phynetlab" have been built. The introduction of IoT-based technologies in such testbeds has given positive results by minimizing delays in material handling activities such as order collection and sorting, resulting in a significant improvement in overall warehouse efficiency. IoT-based warehouse management systems are critical for retaining customers, maximizing product delivery, assuring precise inventory visibility, and cultivating a productive workforce, and solutions have proved to save significant time, improve processing efficiency, and provide real-time, precise inventory tracking. Data analysis from iot devices is especially important in modern warehouse management, allowing for more accurate demand forecasting, addressing security and authentication issues, and considerably improving the agility and visibility of warehouse operations (Yerpude & Singhal, 2018). Aside from increased efficiency, IoT solutions help to reduce expenses through increased production, labour optimisation, and energy savings.

6.1. Case Study: Mid-Size FMCG (Fast-Moving Consumer Goods) Warehouse

The FMCG includes products like food, beverages, personal care, household goods, etc. that have a quick turnover and are in high demand. This case study examines the implementation of IoT in a regional FMCG warehouse to improve operational efficiency. The warehouse covers 30,000 m², manages 12,000 SKUs, and processes 5,000 orders/day. The goal is to evaluate the impact of IoT solutions (like RFID, smart forklifts, real-time condition monitoring, and temperature sensors) on costs, inventory accuracy, OTIF (On-Time In-Full delivery), and pick rate.

The key objectives of implementing IoT were:

- To reduce operational costs (e.g., order picking, energy consumption, shrinkage).
- To improve KPIs such as OTIF, inventory accuracy, and pick rate.
- To calculate the payback period and ROI from IoT investments

Costs: Total annual operating costs dropped from ₹275 lakh to ₹213.4 lakh. The largest saving is in order picking (₹35 lakh), followed by transport (₹8 lakh), storage (₹9 lakh), damage/shrink (₹6 lakh), and energy (₹3.6 lakh). This aligns with guided picking, telemetry-enabled handling, better dock/trailer coordination, improved traceability, and condition monitoring, as shown in Figure 8.

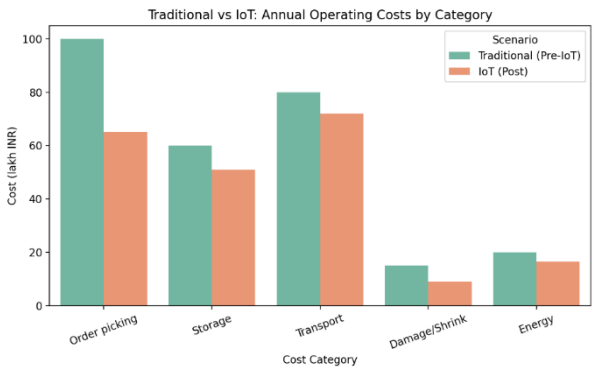


Figure 8. Annual operating costs by category before vs after IoT

Total Savings from IoT

$\Delta C = C_{base} - C_{IoT} = 275 - 213.4 = 61.6$ lakh/year, as shown in Figure 9.

Returns: With a ₹120 lakh CapEx and ₹12 lakh/year OpEx, payback is ~1.95 years on a cash basis; P&L costs decline by ~9.3% vs baseline when amortizing CapEx over 5 years.

$$Payback\ Period\ = \frac{CapEx}{Annual\ Cash\ Savings} = 1.95\ \text{Years}$$

KPIs: OTIF improved from 92% to 98% (+6 pts); inventory accuracy from 95% to 99.5% (+4.5 pts); pick rate from 110 to 150 lines/hour (~26.7% cycle-time reduction); damage/shrink down ~40%; and energy down ~18%. These gains flow from item/lot traceability, guided workflows (RFID + scanners), telemetry, GPS visibility, and MQTT event-driven orchestration.

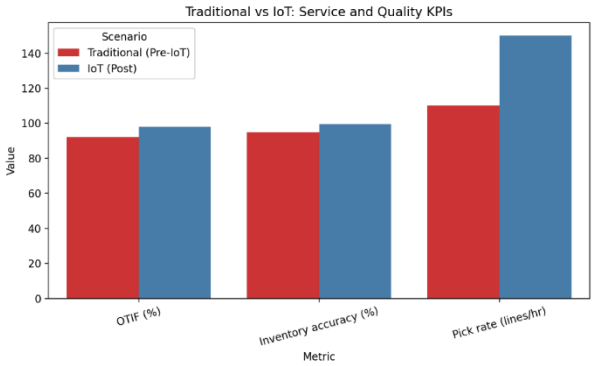


Figure 9. Service and quality KPIs before vs after IoT

Table 3 shows the cost and KPI improvements observed in a typical FMCG warehouse after implementing IoT-based systems. The table compares pre-IoT traditional methods to IoT-enabled optimizations, highlights the key areas where savings and performance gains were achieved.

Table 3. Traditional vs IoT-enabled Warehousing

Aspect	Traditional	IoT-enabled	Improvement
Inventory Accuracy	92–96%	99–99.7%	+3–7 pts
Picking Time	Baseline	−25 - 45 %	Faster
OTIF	90–94%	96–99%	+2–8 pts
Damage Rate	Higher	−20 - 40 %	Lower
Energy Use	Baseline	−10 - 25 %	Lower
Traceability	Batch-level	Item-level	Higher

7. DISCUSSION

The results of this study demonstrate that the transition from traditional manual warehousing to an IoT-enabled environment is not merely a technical upgrade but a fundamental shift in operational logic. By moving away from fragmented, paper-based processes, the warehouse achieved a level of synchronization previously unattainable.

The most striking finding was the ₹61.6 lakh annual saving, driven largely by a ₹35 lakh reduction in order picking costs. This improvement is directly tied to the implementation of RFID-guided picking and wearable scanners, which transformed a high-error manual task into a streamlined, data-driven workflow. The jump in pick rate from 110 to 150 lines/hour represents a 26.7% reduction in cycle time, proving that real-time connectivity eliminates the "information lag" that plagues traditional setups.

The proposed Warehouse IoT Efficiency Index (WIEI) served as a critical tool for balancing quality against cost. While many systems focus solely on speed, the WIEI highlighted that our OTIF (On-Time-In-Full) rate improved by 6 percentage points. This suggests that the MQTT-driven architecture—where the Raspberry Pi acts as a central broker—ensures that the speed gains do not come at the expense of delivery accuracy.

Despite the clear benefits, the ₹120 lakh initial investment (CapEx) remains a significant hurdle for many firms. However, our analysis shows a payback period of approximately 1.95 years, which is highly competitive for industrial technology. This economic viability is supported by secondary gains, such as a 40% reduction in product damage and an 18% drop in energy consumption, achieved through smart forklift telemetry and automated climate control.

We must acknowledge that these gains depend on a stable internet connection and a digitally literate workforce. The "data overloading" mentioned in our limitations remains a risk; therefore, the role of the database module as a centralized, filtered information centre is vital for maintaining actionable insights rather than just raw noise. Ultimately, this study confirms that for a mid-size FMCG warehouse, the convergence of IoT, RFID, and real-time analytics is no longer a luxury but a strategic necessity to remain competitive in a market that demands safe, fast, and low-cost delivery.

8. LIMITATIONS

Integrating IoT into warehouse and logistics operations also gives a series of challenges and limitations which need to be considered carefully. A major challenge is the high cost associated with setting up IoT systems. To implement such technology often involves huge investments in various devices, including sensors, scanners, and management systems. Moreover, IoT technology itself can be complex and requires specialized knowledge and expertise for installation and ongoing maintenance, which may need experts. Security is another important concern. The interconnected nature of IoT systems increases liability to cyberattacks. In addition, the huge volume of data produced by IoT devices can lead to data overloading, complicate the process to identify the relevant information and make informed decisions. Integration issues frequently arise

when attempting to incorporate modern IoT technologies with older systems, which often proves to be an incompatible and challenging process.

IoT systems also depend heavily on stable internet connections; any disruption in connectivity can halt operations, which emphasize the need for reliable network services. The operational demands of IoT devices include continuous power supply, which can lead to increased energy consumption and logistical challenges related to battery replacement or the provision of adequate power sources. Staff training is another necessary investment, as employees must be competent in utilizing new IoT technologies effectively. To maintain and update IoT systems is an ongoing requirement, and regular updates are important to ensure operational efficiency and security, and sometimes, entire devices may need to be replaced to stay current with recent advancements. Lastly, the reliability and accuracy of IoT sensors are pivotal; any malfunction or damage can lead to incorrect data, potentially resulting in broader operational issues. IoT integration into warehouse and logistics operations can significantly enhance efficiency and oversight; it brings with it a complex array of challenges that require strategic planning and robust management to overcome.

9. CONCLUSION

The integration of the IoT for logistics and warehousing operations marks a revolutionary era of improved efficiency, transparency, and optimization. With the proliferation of smart devices along with high-speed networks, the collection and quality of real-time data have become vital in managing the complexity and veracity of customer orders. Traditional manual approaches are no longer compatible with handling the growing volume of activities in this evolving landscape. The primary role of logistics management is to maintain the synchronization of tasks, participants, and stakeholders while delivering the proper commodities to customers on time and in the required condition. Warehouses are now focusing on sales and customer happiness, with order picking accounting for a significant number of operating expenditures. Manual processes have restrictions that impede warehouse productivity and response to consumer demands. IoT, which includes technology such as mobile devices, GPS, and networked devices, allows for smooth data collection and exchange. Because of this interconnection, common items are transformed into smart objects capable of making informed decisions. The logistics industry uses IoT to acquire end-to-end traceability and visibility, improving operational efficiency across a variety of domains such as inventory control, fleet management, asset utilization, security and safety. RFID, GPS systems, and Wireless Sensor Networks (WSNs) enable real-time tracking and tracing of logistical assets and shipments, ensuring delivery quality even in difficult environmental circumstances. IoT enhances warehouse management by allowing for product tracking, demand forecasting, inventory control, and real-time operations.

Customers today expect quick, cost-effective, and secure delivery, which is pushing the use of novel logistics solutions. Companies that do not embrace these improvements risk becoming obsolete. Smart logistics, powered by IoT, will transform the logistics scene, but adoption will be tough due to a knowledge gap and the need to address current challenges. Embracing these advances is no longer a choice; it is a requirement for businesses seeking to thrive in the dynamic logistics world. Addressing multiple challenges, comprehending appropriate scenarios, and charting the road for future improvements are all required for the effective adoption of IoT-based smart logistics. In this ever-changing world, the convergence of IoT and logistics and warehousing holds the potential for increased productivity, cost-effectiveness, and customer happiness. Businesses that use IoT to improve their operations will be better positioned to meet the demands of the modern market as the logistics industry evolves. Smart, data-driven solutions are rapidly paving the way to success in logistics and warehousing, and IoT is at the forefront of this revolution. It's not just a technological transformation; it's a strategic imperative for those in the logistics and warehousing industry who want to stay competitive and customer-focused.

References

Accorsi, R., Bortolini, M., Baruffaldi, G., Pilati, F., & Ferrari, E. (2017). Internet-of-Things paradigm in food supply chains control and management. *Procedia Manufacturing, 11*, 889–895. doi: 10.1016/j.promfg.2017.07.192

Ackerman, K. B. (1990). Warehousing: Origins, history and development. In *Practical handbook of warehousing* (pp. 3–11). Springer.

Al-hamadani, S., & Al-Darraji, I. (2025). Warehouse in industry 4.0 based drone, computer vision, and artificial intelligence technologies: a literature review. *Proceedings on Engineering Sciences*, *7*(1), 517-526. doi: 10.24874/PES07.01D.008

Alho, A., e Silva, J. D., & de Sousa, J. P. (2014). A state-of-the-art modeling framework to improve congestion by changing the configuration/enforcement of urban logistics loading/unloading bays. *Procedia - Social and Behavioral Sciences, 111*, 360–369. doi: 10.1016/j.sbspro.2014.01.067

Ashton, K. (2009). That 'Internet of Things' thing. *RFID Journal, 22*(7), 97–114.

Bardi, E. J., Raghunathan, T. S., & Bagchi, P. K. (1994). Logistics information systems: The strategic role of top management. *Journal of Business Logistics, 15*(1), 71–85.

Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0 implications in logistics: An overview. *Procedia Manufacturing, 1*3, 1245–1252. doi: 10.1016/j.promfg.2017.09.045

Brockman, T. (1999). 21 warehousing trends in the 21st century. *IIE Solutions, 31*(7), 36–41.

Chung, S. H. (2021). Applications of smart technologies in logistics and transport: A review. *Transportation Research Part E: Logistics and Transportation Review, 153*, 102455. doi: 10.1016/j.tre.2021.102455

De Vass, T., Shee, H., & Miah, S. J. (2018). The effect of Internet of Things on supply chain integration and performance: An organizational capability perspective. *Australasian Journal of Information Systems, 22*. doi: 10.3127/ajis.v22i0.1734

Ding, Y., Jin, M., Li, S., & Feng, D. (2021). Smart logistics based on the Internet of Things technology: An overview. *International Journal of Logistics Research and Applications, 24(*4), 323–345. doi: 10.1080/13675567.2020.1754103

Dorsemaine, B., Gaulier, J. P., Wary, J. P., Kheir, N., & Urien, P. (2015). Internet of Things: A definition & taxonomy. In 2015 9th International Conference on Next Generation Mobile Applications, Services and Technologies (pp. 72–77). IEEE. doi: 10.1109/NGMAST.2015.33

Frazelle, E. (2002). *World-class warehousing and material handling.* McGraw-Hill.

Giusto, D., Iera, A., Morabito, G., & Atzori, L. (2010). *The Internet of Things.* Springer.

Gustin, C. M., Daugherty, P. J., & Stank, T. P. (1995). The effects of information availability on logistics integration. *Journal of Business Logistics, 16*(1), 1–21.

Haller, S., Karnouskos, S., & Schroth, C. (2009). The Internet of Things in an enterprise context. In *Future Internet – FIS 2008* (pp. 14–28). Springer. doi: 10.1007/978-3-642-00985-3_2

Hamdy, W., Mostafa, N., & Elawady, H. (2018). Towards a smart warehouse management system. In *Proceedings of the International Conference on Industrial Engineering and Operations Management* (pp. 2555–2563).

Harrison, T. P., Lee, H. L., Neale, J. J., & Whang, S. (2004). E-business and supply chain integration. In *The Practice of Supply Chain Management* (pp. 123–138). Springer.

Jarašūnienė, A., Čižiūnienė, K., & Čereška, A. (2023). Research on impact of IoT on warehouse management. *Sensors, 23*(4), 2213. doi: 10.3390/s23042213

Jianyu, W., Runtong, Z., & Jun, W. (2015). Research on the distribution system in e-commerce logistics based on gridding management. In *2015 International Conference on Logistics, Informatics and Service Sciences* (pp. 1–5). IEEE. doi: 10.1109/LISS.2015.7369701

Jin, Y. L., Gong, A. L., & Liu, S. P. (2013). Study of logistics warehouse management system based on RFID. *Advanced Materials Research, 748*, 1281–1284. doi: 10.4028/www.scientific.net/AMR.748.1281

Karrieva, Y. K., Saenko, I. I., Bachurinskaya, I. N., Agalakova, O. S., & Litvinova, T. N. (2026). Sustainable innovations to raise Quality 5.0 in the transport and logistics complex: international experience and managerial perspective. *Proceedings on Engineering Sciences, 8*(1), 39-46. doi: 10.24874/PES08.01.005

Kim, J. S., Lee, H. J., & Oh, R. D. (2015). Smart integrated multiple tracking system development for IoT-based logistics. *International Journal of Smart Home, 9*(5), 195–204.

Kiritsis, D. (2011). Closed-loop PLM for intelligent products in the era of the Internet of Things. *Computer-Aided Design, 43*(5), 479–501. doi: 10.1016/j.cad.2010.03.007

Lancioni, R. A., & Chandran, R. (1990). The role of packaging in international logistics. *International Journal of Physical Distribution & Logistics Management, 20*(8), 41–43.

Lancioni, R. A., Smith, M. F., & Oliva, T. A. (2000). The role of the Internet in supply chain management. *Industrial Marketing Management, 29*(1), 45–56. doi: 10.1016/S0019-8501(99)00074-0

Lee, I., & Lee, K. (2015). The Internet of Things: Applications, investments, and challenges. *Business Horizons, 58*(4), 431–440. doi: 10.1016/j.bushor.2015.03.008

Lee, S., Tewolde, G., & Kwon, J. (2014). Design and implementation of vehicle tracking system using GPS/GSM/GPRS. In *IEEE World Forum on Internet of Things* (pp. 353–358). IEEE. doi: 10.1109/WF-IoT.2014.6803178

Li, M., Gu, S., Chen, G., & Zhu, Z. (2011). RFID-based intelligent warehouse management system. In *IEEE 8th International Conference on e-Business Engineering* (pp. 178–184). IEEE. doi: 10.1109/ICEBE.2011.47

Liu, T., Liu, J., & Liu, B. (2010). Intelligent warehouse system based on Zigbee WSN. In *IEEE International Conference on Mechatronics and Automation* (pp. 888–893). IEEE. doi: 10.1109/ICMA.2010.5588367

Lopes, Y. M., & Moori, R. G. (2021). The role of IoT in logistics performance. *Revista de Administração Mackenzie, 22*. doi: 10.1590/1678-6971/eRAMR210032

Lou, P., Liu, Q., Zhou, Z., & Wang, H. (2011). Agile supply chain management over the Internet of Things. In *International Conference on Management and Service Science*. IEEE. doi: 10.1109/ICMSS.2011.5998067

Ma, X. (2016). Three-dimensional warehouse automated logistics control system based on ZigBee. *Journal of Harbin University of Science and Technology, 21*(6), 67–72.

Macaulay, G. C. J., & Buckaew, L. (2015). *Internet of Things in logistics.* DHL & Cisco.

Mehmood, Y., Marwat, S. N., Kuladinithi, K., Förster, A., Zaki, Y., Görg, C., & Timm-Giel, A. (2016). M2M potentials in logistics and transportation industry. *Logistics Research, 9*. doi: 10.1007/s12159-016-0143-7

Meyer, G. G., Främling, K., & Holmström, J. (2009). Intelligent products: A survey. *Computers in Industry, 60*(3), 137–148. doi: 10.1016/j.compind.2008.12.001

Pal, A., & Kant, K. (2018). IoT-based sensing and communications infrastructure. *Computer, 51*(2), 76–80. doi: 10.1109/MC.2018.1451669

Pienaar, W. J., & Vogt, J. J. (2012). *Business logistics management*. Oxford University Press.

Shin, M. S., Ko, M., Ju, Y., Jung, Y., & Lee, B. (2013). Context-aware robot control system for logistics. *Studies in Informatics and Control, 22*(1), 71–80.

Song, Y., Yu, F. R., Zhou, L., Yang, X., & He, Z. (2020). Applications of IoT in smart logistics. *IEEE Internet of Things Journal, 8*(6), 4250–4274. doi: 10.1109/JIOT.2020.3022485

Staudt, F. H., Alpan, G., Di Mascolo, M., & Rodriguez, C. M. (2015). Warehouse performance measurement. *International Journal of Production Research, 53*(18), 5524–5544. doi: 10.1080/00207543.2015.1030467

Sternberg, H., Hagen, A., Paganelli, P., & Lumsden, K. (2010). Intelligent cargo transportation system. *World Journal of Science, Technology and Sustainable Development, 7*(3), 253–262.

Tadejko, P. (2015). Application of IoT in logistics. *Economics and Management, 7*(4), 54–64.

Tang, C. P., Huang, T. C., & Wang, S. T. (2018). Impact of IoT implementation. *Telematics and Informatics, 35*(7), 2038–2053. doi: 10.1016/j.tele.2018.07.007

Tejesh, B. S. S., & Neeraja, S. (2018). Warehouse inventory system using IoT. *Alexandria Engineering Journal, 57*(4), 3817–3823. doi: 10.1016/j.aej.2018.02.003

Tran-Dang, H., Krommenacker, N., Charpentier, P., & Kim, D. S. (2022). IoT for logistics. *IETE Technical Review, 39*(1), 93–121. doi: 10.1080/02564602.2020.1749895

Tseng, Y. Y., Yue, W. L., & Taylor, M. A. (2005). The role of transportation in logistics. *Proceedings of the Eastern Asia Society for Transportation Studies, 5*, 1657-1672.

Uckelmann, D., Harrison, M., & Michahelles, F. (2011). *Architecting the Internet of Things.* Springer.

Williams, L. R., Nibbs, A., Irby, D., & Finley, T. (1997). Logistics integration. *Journal of Business Logistics, 18*(2), 31–41.

Yerpude, S., & Singhal, T. K. (2018). Smart warehouse with IoT. *International Journal of Pure and Applied Mathematics, 118*(24), 1–5.

Zhang, Y., Zhao, L., & Qian, C. (2017). IoT-enabled supply chain. *Industrial Management & Data Systems, 117*(9), 1890–1905. doi: 10.1108/IMDS-12-2016-0543

Ginnel Quadras
Department of Mechanical and Industrial Engineering,
Manipal Institute of Technology,
Manipal Academy of Higher Education,
Manipal,
Karnataka 576104,
India
Ginnel.mitmpl2022@learner.manipal.edu
ORCID 0009-0006-7810-9139

Princy Randhawa
Department of Computer Science and Engineering (AI&ML),
Dayananda Sagar University,
Bengaluru,
India
Princy-aiml@dsu.edu.in
ORCID 0000-0001-6356-8718

Jitendra Kumar Jaiswal
Department of Computer Science and Engineering (AI&ML),
Dayananda Sagar University,
Bengaluru,
India
Jitendrajaiswal-aiml@dsu.edu.in
ORCID 0000-0002-7769-9505

Ramakrishna Garine
Department of Mechanical Engineering,
University of North Texas,
Denton, 76205,
USA
ramakrishnagarine@gmail.com
ORCID 0009-0000-6076-4086

Nikhil Kassetty
Department of Computer Science,
University of Missouri,
Kansas City,
MO 64110,
USA
nikhilkassetty.cs@gmail.com
ORCID 0009-0003-7540-3656

Nithesh Naik
Department of Mechanical and Industrial Engineering,
Manipal Institute of Technology,
Manipal Academy of Higher Education,
Manipal,
Karnataka 576104,
India
nithesh.naik@manipal.edu
ORCID 0000-0003-0356-7697