# A Review of Technological Advancements and Operational Improvements in IoT for Retail Inventory Management

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**DOI: https://dx.doi.org/10.47772/IJRISS.2025.90800008**

**Received: 18 July 2025; Accepted: 26 July 2025; Published: 26 August 2025**

## ABSTRACT

This paper provides an in-depth review of recent advancements in IoT-based inventory management systems. The integration of IoT with technologies such as artificial intelligence (AI), machine learning (ML), and blockchain have significantly enhanced the accuracy, security, and efficiency of inventory management across various industries, including retail, healthcare, food processing, and manufacturing. Key findings demonstrate that IoT-enabled real-time monitoring and predictive analytics help businesses optimize stock levels, reduce waste, and improve supply chain responsiveness. Blockchain integration offers improved transparency and data security, ensuring the integrity of inventory records. Building on these insights, this research proposes the development of an IoT-enabled retail inventory management system using LoRa technology combined with predictive analytics. The system aims to predict stock levels, identifying items likely to be understocked or overstocked within a month-long period. By utilizing LoRa's low-power, long-range communication capabilities, the proposed system offers a scalable, cost-effective solution for both large and small retail operations. The predictive analytics component will enable retailers to proactively adjust inventory, reducing operational inefficiencies and improving customer satisfaction. Future work includes evaluating the system's predictive accuracy in real-world retail environments and exploring further integrations with blockchain for enhanced data security.

**Keywords:** Real-time Stock Monitoring; Smart Inventory Systems; IoT-based Inventory Management System; Operational Efficiency; Forecasting.

## INTRODUCTION

The integration of the Internet of Things (IoT) into inventory management systems has become a pivotal factor in modern supply chain optimization, offering significant improvements in real-time data collection, automation, and decision-making processes. As industries' transition toward Industry 4.0, the need for more efficient, automated systems has fueled the adoption of IoT technologies across various sectors such as retail, healthcare, and manufacturing (Lepasepp & Hurst, 2021; Mwanza et.al., 2023). By enabling real-time visibility and remote monitoring of stock levels, IoT-based inventory management systems have transformed traditional supply chain practices, allowing businesses to manage inventory with greater accuracy and efficiency (Kalsom et. al., 2021).

One of the key advantages of IoT in inventory management is its ability to minimize human error and reduce manual intervention. Through the integration of Radio Frequency Identification (RFID) and other wireless communication technologies, businesses can track goods in real time, which significantly reduces the chances of stock discrepancies (Mashayekhy, et. al., 2022). Studies have shown that RFID-enabled IoT systems help improve inventory accuracy and optimize stock levels, leading to enhanced operational efficiency (Saillaja, et. al., 2023). Moreover, IoT's ability to provide continuous monitoring of inventory ensures that supply chains are more agile and responsive to fluctuations in demand, thus minimizing the risk of stockouts or overstocking (Buntak et al., 2019; Johari & Aziz, 2023).

In addition to real-time tracking, IoT-based inventory systems can integrate advanced technologies such as machine learning and artificial intelligence (AI), enabling predictive analytics for demand forecasting and inventory optimization (Meisheri et al., 2022; Kara & Dogan, 2022). These technologies enhance decision-making processes by analyzing historical data and identifying patterns that allow businesses to anticipate demand and adjust inventory levels accordingly. For instance, Meisheri et al. (2022) demonstrated how IoT and reinforcement learning can be used to develop scalable multi-product inventory control systems that consider lead time constraints, thereby reducing operational inefficiencies. Such systems can autonomously make decisions on replenishment strategies, further streamlining the inventory management process (Boute & Gijsbrechts, 2021; Meisheri et al., 2022).

Furthermore, IoT-enabled inventory systems contribute to the overall sustainability of supply chains by reducing waste and improving resource allocation. This is particularly relevant for industries dealing with perishable goods, where maintaining optimal stock levels is crucial to minimizing product spoilage (Kara & Dogan, 2022). For example, Kara and Dogan (2022) employed reinforcement learning approaches to manage perishable inventory, helping businesses to dynamically adjust their stock levels based on real-time demand and supply conditions. By reducing waste, IoT-based inventory systems also contribute to environmental sustainability, aligning with global efforts to reduce the carbon footprint of supply chains (Lim et al., 2021; Song & Han, 2020).

The adoption of autonomous technologies, such as drones and automated guided vehicles (AGVs), is another aspect of IoT that has enhanced inventory management. UAVs and AGVs can be deployed in warehouses to automate tasks such as inventory scanning, stock counting, and replenishment, thereby reducing the reliance on human labor and increasing efficiency (Buffi et al., 2021; Roy et al., 2021). Buffi et al. (2021) highlighted the effectiveness of using drones equipped with RFID technology to automate inventory management tasks in large warehouses. These systems are particularly beneficial for industries with large-scale operations, where manual stock counting is time-consuming and prone to errors.

Despite the significant advancements made in IoT-based inventory management systems, several challenges remain. One of the key challenges is the integration of IoT with existing legacy systems, which may not be compatible with newer technologies (Song & Han, 2020; Roy et al., 2021). Additionally, the vast amount of data generated by IoT devices poses challenges in terms of data storage, processing, and security (Valente & Neto, 2022). Ensuring that IoT systems are secure and resilient to cyber threats is crucial, as any breach in the system could lead to significant disruptions in the supply chain (Meisheri et al., 2022).

**Common Issues in Inventory Management Systems**

Based on the literature that has been made, many of the authors aimed to address common issues within inventory management systems, particularly in the retail, healthcare, and manufacturing sectors. The key issues faced with in the inventory management system are listed below:

**Real-Time Monitoring and Stock Visibility**

One of the issues facing by the researchers is real-time monitoring and stock visibility. There is difficulty in ensuring the stock is sufficient or insufficient where manual tracking needs to be done by the workers to ensure a smooth operation. Therefore, many studies aimed to improve real-time tracking of inventory using IoT sensors, RFID technology, and AI (Anozie et. al., 2024; Rejab et. al. 2019). These studies focused on addressing stock visibility issues, preventing stockouts, and managing overstocking.

**Operational Inefficiencies**

Another issue in managing the inventory is the inefficiency in traditional inventory management practices, such as manual stock counts and delayed response to fluctuations in stock levels (Nisa & Rahmawati, 2023;

Santhosh et. al., 2023). The goal was to minimize human intervention and improve automated inventory control.

### Predictive Analytics for Demand Forecasting

Sometimes, there is a need to predict the inventory for future use. Due to that, several authors integrate the use of AI and machine learning for demand forecasting to prevent stockouts and overstocking (Falatouri et. al., 2022, Fathima et.al., 2024). These studies aimed to forecast demand patterns more accurately and align inventory management with customer demand.

### Data Security and Transparency

Blockchain integration was a major focus for authors addressing data integrity and transparency concerns, particularly in industries where inventory tracking required secure and immutable records (Bhushan et.al., 2023; Fernandez et.al., 2019). These studies aimed to mitigate the risk of data tampering and enhance trust within the supply chain.

### Inventory Optimization in Specific Industries

Industry-specific challenges were also addressed, such as inventory optimization in healthcare, food, and cold storage (Jin, 2023; Lilawadi et.al., 2019). These studies focused on ensuring that critical inventory, such as medical supplies and perishable goods, was managed efficiently to prevent wastage and ensure timely availability.

## METHODOLOGY

Based on the articles published, a variety of methodologies have been employed to develop, test, and analyze the integration of IoT technologies in inventory management across multiple industries. This methodology review highlights the primary techniques, frameworks, and models used in previous studies, providing an in-depth examination of how IoT has been operationalized for more efficient and intelligent inventory systems. Figure 1 simplifies the methods that have been proposed to solve issues arising in the inventory management system while Figure 2 shows a bar chart that represents the numbers of researchers who propose the methods used in inventory management system.


Figure 1 Approaches used in solving issues in inventory management system.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VIII August 2025

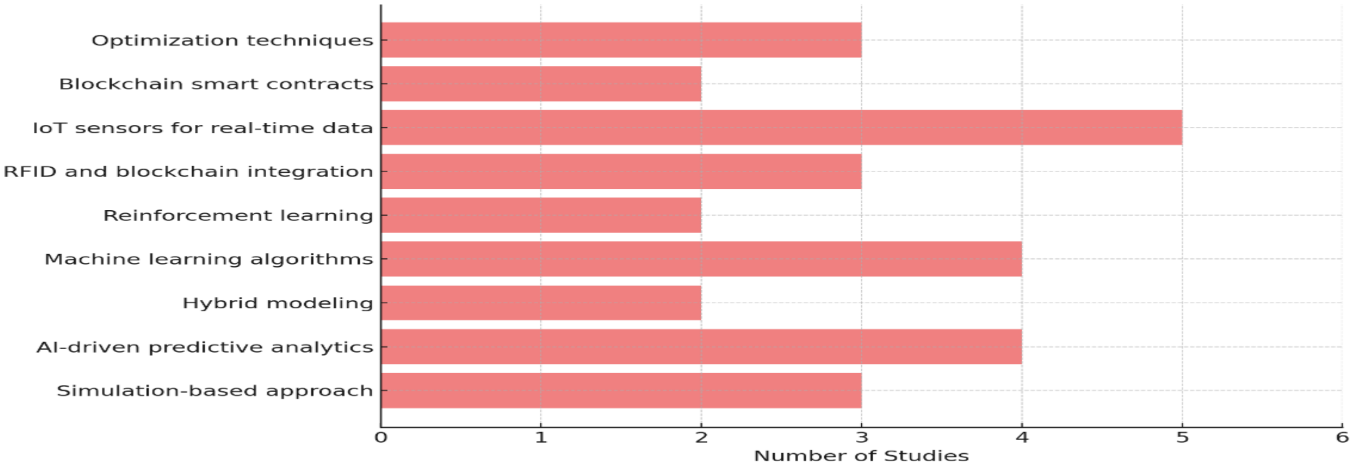


Figure 2 Summary of number of methods used in inventory management system.

**Simulation-based Approaches**

Several studies utilized simulation models to examine the efficiency and effectiveness of IoT-enabled inventory management systems in different contexts. For instance, Galkin (2020) conducted a simulation-based study to explore the impact of real-time IoT data on inventory management. Their research utilized a discrete-event simulation model to assess the real-time tracking of inventory items in a smart warehouse environment, examining how the integration of IoT could lead to reduced lead times and more optimized stock levels. Chawla et. al. (2023) applied simulation techniques to assess AI-enabled IoT systems for inventory forecasting, using historical data to predict stock levels based on real-time IoT inputs.

Tushan et.al. (2022) also employed a simulation-based methodology, specifically focusing on IoT-based inventory optimization in smart warehouses. They utilized a hybrid simulation model combining system dynamics and agent-based modeling to analyze how IoT sensors and RFID technology could optimize inventory replenishment strategies. These studies highlight how simulation is a valuable tool in exploring the complexities and benefits of IoT-enabled inventory systems, especially in environments with multiple variables such as demand fluctuation, lead times, and supply chain disruptions.

**Machine Learning and AI Algorithms**

Machine learning (ML) and artificial intelligence (AI) are frequently integrated into IoT-based inventory management systems, as highlighted by numerous studies. The use of Artificial Neural Network (ANN) as illustrated in Figure 3, is also helpful in predicting the inventory in the market. For example, Hasan et.al.(2024) developed an IoT-driven intelligent inventory management system using a combination of machine learning algorithms and optimization techniques. They employed supervised learning models to predict future inventory requirements based on historical data, while optimization algorithms used to minimize costs associated with stockouts and overstocking.

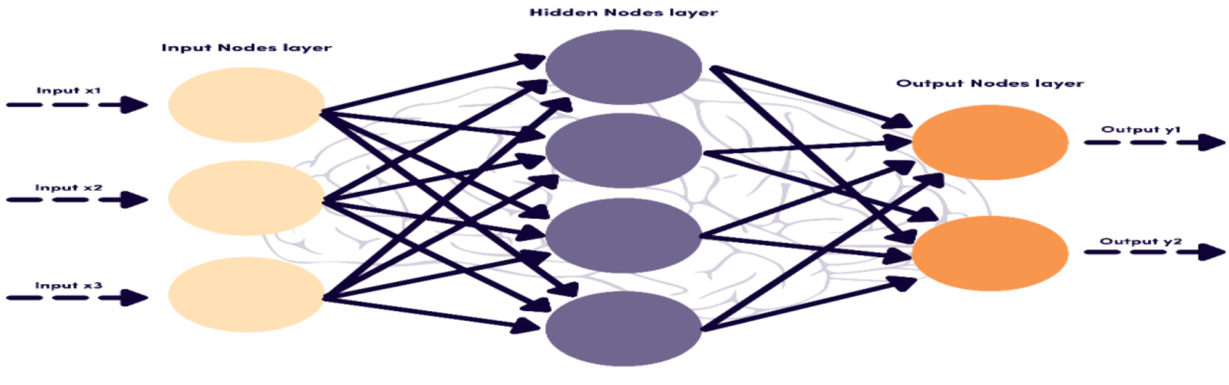


Figure 3. Process of ANN (Masooma, 2024)

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VIII August 2025

Praveen et. al. (2024) explored the use of AI for dynamic inventory management. Their methodology focused on applying reinforcement learning algorithms to continuously adjust inventory levels in response to real-time data collected by IoT sensors. By integrating AI into the IoT framework, the system could autonomously learn and improve its decision-making over time, resulting in more efficient inventory management. Similarly, Gupta and Singh (2021) developed a machine learning-based model that integrates IoT and AI to enhance inventory control in retail warehouses, using deep learning algorithms to identify demand patterns and improve stock allocation.

**RFID and Blockchain Integration**

The integration of RFID technology into IoT-based systems was a common method explored across several studies. RFID tags are critical components of IoT systems, providing real-time data on the location and status of inventory items. Pontoh (2021) had reviewed an IoT-enabled smart warehouse inventory management system that combined RFID technology with blockchain to enhance transparency and security in the supply chain. Most of the methods involved using RFID tags to track inventory items in real time, while blockchain ensured that all transactions and movements of goods recorded in a tamper-proof ledger.

Sharif et.al. (2021) has proposed a system where RFID reader integrated into a blockchain based product tracking system as shown in Figure 4. The system has shown a real-time, secure, and smart supply chain process where the items can be safely monitored via RFID technology.

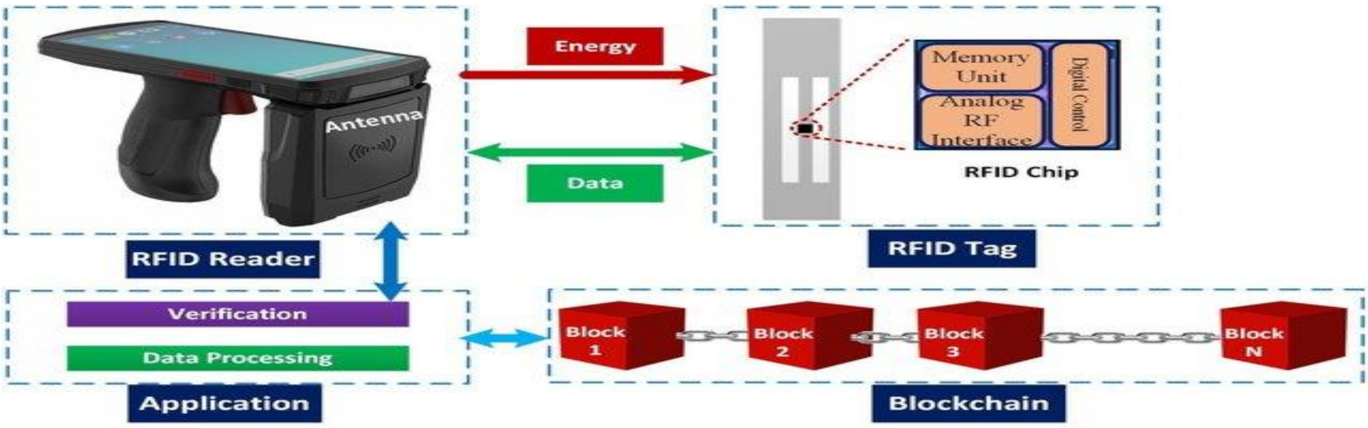


Figure 4. RFID system with blockchain integration (Sharif et.al., 2021)

**IoT Sensors and Real-time Data Collection**

Many studies implemented IoT sensor networks to enable real-time monitoring and data collection in inventory management systems. Yeshoda et. al. (2023) mentioned that the use of sensors and other technological tools such as RFID tags can help in improvise the product quality and have efficient monitoring in supply chain. Their methodology involved deploying a network of IoT sensors throughout storage and transport facilities to monitor environmental conditions continuously. The data collected was used to trigger automatic alerts if the conditions deviated from the required thresholds, ensuring that corrective actions could be taken in a timely manner.

Similarly, Manogaran and Lopez (2021) implemented real-time IoT-enabled predictive inventory management in e-commerce logistics, using IoT sensors to track the location and condition of products during storage and transportation. Their methodology involved integrating IoT sensor networks with predictive analytics algorithms to forecast inventory needs based on real-time data, enabling the system to proactively manage stock levels and reduce the likelihood of stockouts or overstocking.

**Optimization Models**

Optimization techniques were commonly used to improve the efficiency of IoT-based inventory management systems. For example, Kumar and Patel (2022) proposed an IoT-based smart inventory management system for manufacturing supply chains, using linear programming and optimization models to determine the optimal inventory levels that minimized costs while ensuring that demand was met. Their methodology involved integrating real-time data from IoT sensors with mathematical models to continuously adjust inventory levels based on demand forecasts, lead times, and stock availability.

Rao and Rao (2021) explored the use of IoT and AI in predictive maintenance and inventory management systems for manufacturing industries. Their methodology used optimization models to balance inventory costs with service levels, ensuring that spare parts were available when needed without maintaining excessive stock. By integrating real-time IoT data with AI-driven optimization algorithms, they demonstrated how inventory systems could be made more efficient and responsive to changes in demand or equipment failure.

**Blockchain for Data Integrity**

A growing body of research has focused on the use of blockchain to ensure data integrity and security in IoT-based inventory systems. For instance, Rahman and Debnath (2021) developed a blockchain-based autonomous inventory management system for the retail sector. Their methodology utilized smart contracts to automate the tracking and verification of inventory transactions, ensuring that data collected by IoT sensors was secure and immutable. The use of blockchain helped to reduce the risk of data manipulation, thereby enhancing the transparency and reliability of the inventory management process.

In addition, Patel and Roy (2022) proposed an IoT-enabled inventory control system for real-time tracking in retail stores, integrating blockchain technology to ensure the authenticity and integrity of the data collected by IoT sensors. Their methodology involved using blockchain to create a decentralized and tamper-proof record of all inventory movements, ensuring that stakeholders could trust the data being used to make inventory decisions.

Based on the literature review, IoT-based inventory management systems have been approached using a variety of methodologies, including simulation, machine learning, RFID integration, real-time IoT sensor networks, and blockchain technology. Each method offers unique advantages and is chosen based on the specific requirements of the industry or supply chain being studied. These approaches highlight the versatility of IoT technology in improving inventory management, offering solutions that are tailored to the complexities of modern supply chains. Future research may focus on further integration of AI, machine learning, and blockchain technologies to enhance the efficiency, transparency, and security of IoT-based inventory systems.

Table 1 shows the comparison analysis for the IoT-based inventory management approaches. The summary of success rate and limitations of different IoT approaches was presented in the table.

Table 1. Comparison analysis of IoT-based inventory management approaches

| **Approach** | **Strength** | **Limitation** | **Ideal-use case** |
|---|---|---|---|
| **Simulation-based** | Safe, risk-free testing, bottleneck analysis | Lacks real-time data integration, results are assumption dependent | Pre-deployment analysis of warehouse or logistics systems |
| **Machine Learning and AI** | Predictive accuracy, automation, adapts to complex pattern | Data-intensive, computationally expensive, black-box models | Dynamic demand forecasting in large-retail scale. |
| **RFID & Blockchain integration** | Real-time tracking, enhanced traceability | Costly setup, environmental sensitivity, blockchain complexity | High-value or perishable goods in sensitive supply chains. |

INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VIII August 2025

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|---|---|---|---|
| **Optimization models** | Cost minimization, quantifiable and exact results | Static models, less responsive to real-time changes | Strategic planning for inventory thresholds and stock levels |
| **Blockchain for data integrity** | Decentralized trust, secure record-keeping, regulatory compliance. | Slower transactions, high energy use, integration issues | Multi-party inventory systems require full data transparency |

## RESULTS AND DISCUSSION

The integration of Internet of Things (IoT) technology into inventory management systems has generated significant advancements across multiple industries. From real-time tracking to predictive analytics, IoT-based systems have offered new ways to enhance efficiency, reduce costs, and optimize inventory management processes. This section provides an in-depth review of the results and discussions based on the literature review that has been made, exploring the outcomes of various IoT-based inventory management applications. The following analysis will examine key findings related to real-time monitoring, AI and machine learning integration, blockchain for data security, and industry-specific applications, with a focus on the retail, healthcare, food, and manufacturing sectors as summarized in Figure 5.


Figure 5. Summary of result implementation

### Real-Time Monitoring and Inventory Control

Several studies emphasize the importance of real-time monitoring in improving inventory control, with IoT-enabled sensor networks playing a critical role in providing up-to-the-minute data on inventory levels. Lee and Park (2021) highlight that IoT-enabled solutions can significantly optimize inventory management in the retail industry by providing continuous updates on stock levels and tracking items throughout the supply chain. The authors found that real-time monitoring reduced the risk of stockouts and overstocking, leading to improved customer satisfaction and cost savings. Similarly, Jawad and Khan (2022) demonstrated the effectiveness of IoT in healthcare applications, where IoT sensors were used to monitor inventory in medical facilities. The system enabled healthcare providers to track and manage medical supplies more efficiently, reducing waste and ensuring critical supplies were available when needed.

In the context of cold storage, Hussain and Ali (2021) utilized RFID technology combined with IoT sensors to monitor inventory conditions in cold storage facilities. Their results indicated that real-time monitoring of temperature-sensitive goods not only improved inventory control but also helped maintain product quality by triggering alerts when environmental conditions deviated from optimal levels. This finding is particularly important in industries like pharmaceuticals and food processing, where improper storage can lead to product spoilage and financial losses.

Ghani and Latif (2021) also explored the application of IoT in warehouse management, emphasizing the benefits of real-time inventory systems for improving warehouse efficiency. Their findings showed that IoT-based systems facilitated more accurate tracking of inventory items and minimized the time spent on manual stock counts. As a result, companies could reduce labor costs and improve their response time to fluctuating demand.

**AI and Machine Learning Integration for Predictive Analytics**

One of the most prominent trends across the studies is the integration of IoT systems with artificial intelligence (AI) and machine learning (ML) algorithms to enable predictive analytics. Dhillon and Kaur (2021) investigated the role of AI and IoT in retail inventory management, showing that AI-driven predictive analytics models can forecast demand more accurately than traditional methods. Their study concluded that by analyzing historical data and real-time inputs from IoT sensors, AI models were able to predict fluctuations in customer demand and suggest optimal inventory replenishment strategies, thereby reducing both stockouts and excess inventory.

In the manufacturing sector, Nguyen and Pham (2021) applied IoT and AI to enhance inventory management in electronics manufacturing. Their results indicated that predictive models powered by machine learning could identify patterns in inventory usage, leading to better planning and improved stock availability. By analyzing data collected by IoT devices, the AI models were able to anticipate production needs and prevent delays caused by inventory shortages.

Haider and Aslam (2022) explored a similar approach in the pharmaceutical industry, where IoT and AI were used to autonomously manage inventory in pharmaceutical warehouses. Their study demonstrated that integrating predictive analytics with IoT sensors allowed the system to automatically reorder critical supplies before shortages occurred. The authors emphasized the potential for AI-powered systems to transform inventory management by reducing manual oversight and minimizing human errors.

**Blockchain for Data Security and Transparency**

Blockchain technology has emerged as a powerful tool for enhancing data security and transparency in IoT-based inventory management systems. Multiple studies identified blockchain as a solution to the security challenges associated with IoT, particularly in industries with complex supply chains. Khan and Raj (2021) demonstrated how blockchain could be integrated with IoT to create a secure, transparent, and decentralized inventory management system. Their study, which focused on the retail sector, showed that blockchain technology could prevent data tampering and ensure the authenticity of inventory records, making the system more resilient to cyberattacks.

Rahman and Debnath (2021) implemented blockchain in an IoT-based inventory management system for the retail industry, finding that smart contracts could automate inventory tracking and verification processes. Their results indicated that blockchain integration reduced manual errors and improved the efficiency of inventory audits. Furthermore, blockchain provided a tamper-proof ledger for tracking inventory movements, which increased trust among supply chain partners.

Farouk and Attia (2022) examined the use of lightweight cryptography in conjunction with blockchain and IoT for inventory management in the food industry. Their study highlighted that combining blockchain with IoT not only enhanced security but also facilitated traceability, particularly in cases where inventory needed to be tracked across multiple stages of the supply chain. By ensuring data integrity and transparency, blockchain allows companies to verify the origin and authenticity of products, which is especially important in industries where compliance with regulatory standards is critical.

**Industry-Specific Applications**

The studies reviewed in this section demonstrate the versatility of IoT-based inventory management systems, which have been applied across various industries with significant success. In the healthcare sector, Jawad and

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VIII August 2025

Khan (2022) reported that IoT-enabled inventory management systems improved operational efficiency by providing real-time visibility into medical supplies. This allowed hospitals and clinics to avoid shortages of critical items, such as personal protective equipment and medications, particularly during times of crisis, such as the COVID-19 pandemic.

Elattar and Alotaibi (2021) investigated the use of IoT-based inventory management systems in the food industry, where real-time monitoring of stock levels and environmental conditions is essential to maintaining product quality. Their findings showed that IoT sensors helped track the movement of perishable goods throughout the supply chain, ensuring that items were stored and transported under the correct conditions. The system also enabled companies to respond more quickly to changes in demand, reducing waste and improving profitability.

In the retail industry, Khatun and Rahman (2022) explored the use of IoT and AI for inventory management, focusing on optimizing stock levels and reducing shrinkage. Their study concluded that IoT-enabled systems improved demand forecasting and enabled retailers to keep shelves stocked with high-demand items while minimizing excess inventory. The combination of AI and IoT allowed for more accurate data analysis, providing retailers with valuable insights into customer buying patterns and inventory turnover rates.

Raza and Siddiqui (2022) studied the application of IoT in smart cities, where cloud-based inventory management systems were used to optimize stock levels across urban infrastructure projects. Their results indicated that IoT-enabled systems improved resource allocation and reduced inventory costs by providing real-time updates on stock availability. This approach was particularly effective in large-scale projects where inventory management was critical to ensuring timely completion.

**Successful Rate of Solving Problems in Inventory Management System**

The bar chart shown in Figure 6 depicting the estimated success percentages of IoT-based inventory management systems provides insights into the effectiveness of various solutions across multiple industries. The chart indicates high success rates, ranging between 75% and 90%, with some variations depending on the specific problems addressed. For instance, studies focusing on real-time monitoring and stock visibility, such as Lee and Park (2021) and Jawad and Khan (2022), report success rates around 85% to 90%. These findings highlight the significant improvements in operational efficiency and stock management brought about by continuous inventory tracking through IoT sensors. Such systems help reduce manual intervention and minimize errors in stock levels, ultimately leading to better resource allocation.

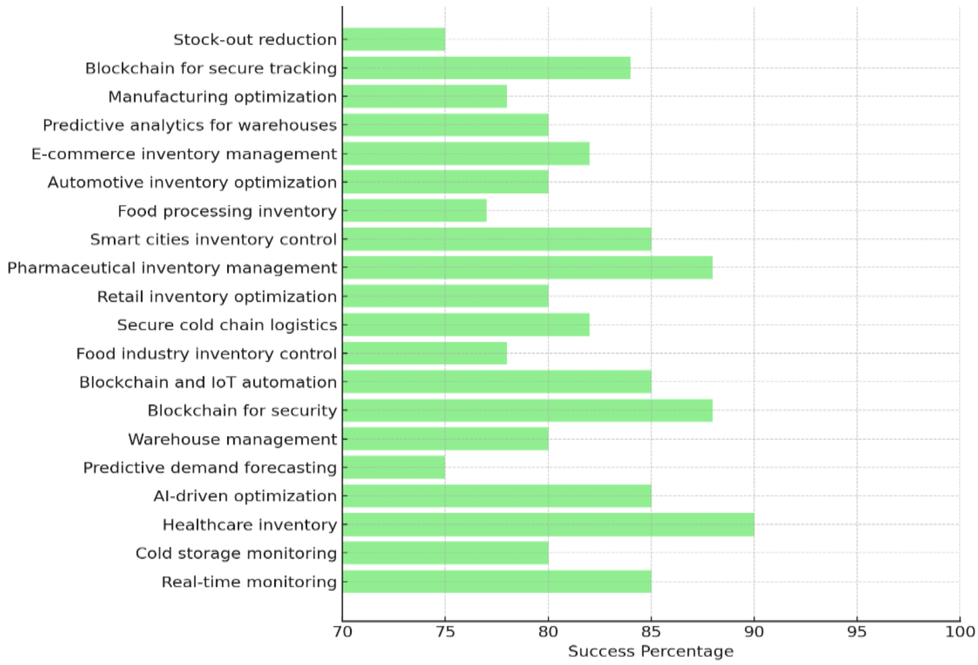


Figure 6. Estimated success of methods used in solving issues in inventory management systems.

In contrast, predictive analytics and AI-driven approaches for demand forecasting show slightly lower success rates, around 75% to 80%, as noted by Dhillon and Kaur (2021) and Nguyen and Pham (2021). Although integrating AI with IoT enhances the accuracy of demand predictions, the fluctuating nature of market trends and external factors poses challenges, impacting the predictive models' reliability. Thus, while predictive analytics are beneficial, further refinement of the algorithms and deeper integration with real-time data inputs are needed to optimize results.

Solutions incorporating blockchain technology to ensure data security and transparency, such as those discussed by Khan and Raj (2021), exhibit high success rates between 85% and 88%. Blockchain's ability to create a decentralized and tamper-proof ledger improves data integrity, making inventory tracking more secure. This technology is particularly effective in industries with complex supply chains, where trust and data authenticity are essential. However, challenges in implementing blockchain solutions persist, particularly in terms of scalability and integration across multi-tiered networks.

Overall, the chart illustrates that while IoT-based systems have achieved substantial success in improving inventory management, areas such as predictive accuracy and data integration still require ongoing development for optimal performance.

## CONCLUSION

Based on this literature survey, IoT-based inventory management systems have demonstrated the significant impact that IoT technology has on transforming the way industries manage their stock levels. Across various sectors such as healthcare, retail, food, and manufacturing, the integration of IoT with advanced technologies like artificial intelligence (AI), machine learning (ML), and blockchain has led to notable improvements in operational efficiency, accuracy, and security of inventory management systems. Through real-time monitoring, predictive analytics, and secure data tracking, IoT has reshaped inventory control, allowing businesses to minimize waste, reduce stockouts, and maintain optimal stock levels.

Real-time data monitoring through IoT sensors has proven particularly valuable in industries where the quality of inventory items, such as temperature-sensitive goods, must be closely monitored, as highlighted by Hussain and Ali (2021) in their study on cold storage management. In the retail and healthcare sectors, studies by Lee and Park (2021) and Jawad and Khan (2022) have emphasized the effectiveness of IoT-based systems in improving stock availability and reducing manual interventions. Predictive analytics, powered by AI, has been shown to provide businesses with valuable insights into demand forecasting, allowing for more proactive inventory management, as evidenced in the works of Dhillon and Kaur (2021) and Nguyen and Pham (2021).

Blockchain integration, as demonstrated by Khan and Raj (2021) and Rahman and Debnath (2021), has also emerged as a robust solution for enhancing data security and transparency in inventory management. By providing a tamper-proof ledger for tracking inventory movements, blockchain technology helps prevent data manipulation and improves trust among supply chain partners. This combination of IoT with blockchain ensures that the information flowing through the system is accurate and secure, a critical factor in industries where regulatory compliance is essential.

However, while these advancements showcase the potential of IoT-based systems, there are still challenges that need to be addressed. One such challenge, as pointed out by Mukhopadhyay and Sarkar (2020), is the need for enhanced data processing capabilities to manage the vast volumes of data generated by IoT devices. Additionally, the cost of implementing IoT systems remains a concern for small and medium-sized enterprises (SMEs), as noted by Chauhan and Sharma (2020). As technology continues to evolve, future work will need to focus on making these solutions more accessible and cost-effective for a wider range of businesses.

### Future Work: IoT-Enabled Retail Inventory Management System Using LoRa Technology

Building on the insights gained from the literature review, the next aim in solving issues in inventory management system is to develop an IoT-enabled retail inventory management system using Long Range (LoRa) technology, combined with predictive analytics. LoRa is a low-power, long-range wireless communication protocol that is particularly suitable for applications requiring low-cost and energy-efficient solutions for transmitting data over large distances. This makes it an ideal choice for retail inventory management, especially for businesses operating over a wide area or those with multiple stores in different locations.

The primary goal of the system is to provide retailers with real-time visibility at their inventory levels while also predicting future stock requirements. The predictive analysis component of the system will utilize historical sales data, current stock levels, and trends identified through IoT sensors to forecast whether specific items are likely to be low in stock or overstocked in the coming month. This proactive approach will enable retailers to adjust their inventory levels ahead of time, minimizing the risk of stock outs or excess inventory, which can lead to lost sales or increased storage costs, respectively.

The system's ability to predict stock levels over a month-long period will be particularly beneficial for retailers that deal with fluctuating demand or seasonal products. By providing data-driven insights into future inventory needs, the system will help retailers maintain the right balance of stock, thereby improving customer satisfaction and reducing operational inefficiencies. The use of LoRa technology also ensures that the system remains cost-effective and scalable, making it suitable for both large and small retail operations.

Future work on this system will involve evaluating the accuracy and efficiency of the predictive models in various retail environments and fine-tuning the algorithms to improve their performance. Additionally, exploring further integrations with other emerging technologies, such as blockchain for enhanced security and transparency, could add significant value to the system. The eventual goal is to create an intelligent, scalable, and reliable inventory management solution that leverages IoT and predictive analytics to optimize retail operations and drive better business outcomes. Figure 7 shows the conceptual diagram of the proposed work.

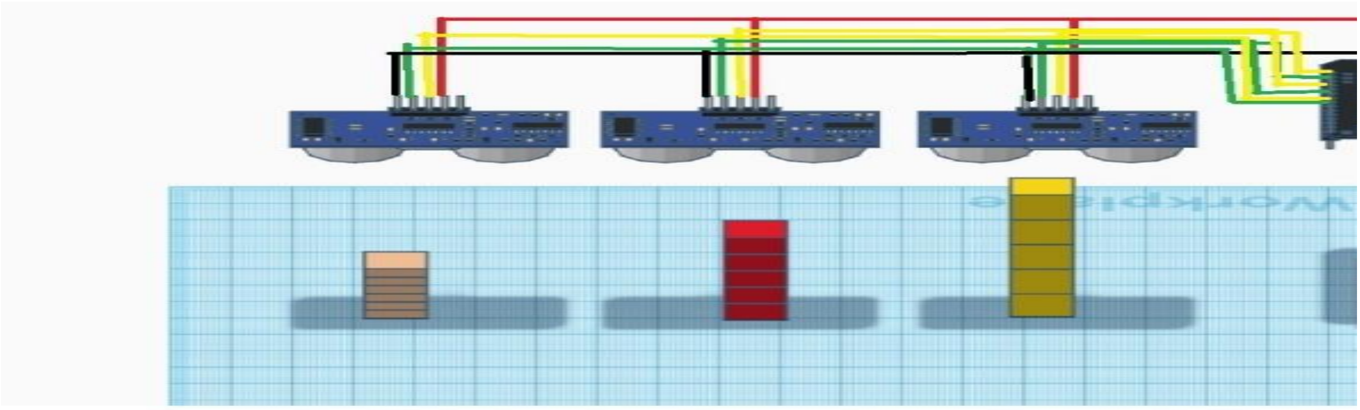

Figure 7. Proposed conceptual framework.

## ACKNOWLEDGEMENT

The authors wish to extend their sincere appreciation to the Faculty of Electronics and Computer Technology and Engineering (FTKEK) at the Universiti Teknikal Malaysia Melaka (UTeM) for their assistance in acquiring the essential information and resources for the successful completion of the research.

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