Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

Smart Dukan - Connected Retail with Smart Shelves and Inventory Management

Dhananjai Pratap Singh[1], Rachi Singh[2] , Simra Sarfaraz[3] , Shivi Yadav[4] , Praful Saxena[5]

Students[1,2,3,4] , Associate Professor[5],

Department of Computer Science & Engineering

Moradabad Institute of Technology, Moradabad, India

dhananjaips111@gmail.com[1]

rachisingh906@gmail.com[2]

simrasarfaraz436@gmail.com[3]

shivi.yadavvv28@gmail.com[4]

shyam.praful@gmail.com[5]

Abstract

The advent of the Internet of Things (IoT) has ushered in a transformative era for retail operations, markedly enhancing automation, real-time tracking, and intelligent inventory management. Central to these advancements are smart shelves—sophisticated systems that integrate IoT devices, sensors, and RFID (Radio Frequency Identification) technology to monitor stock levels, product placements, and customer interactions with unprecedented precision. This research introduces a comprehensive system that amalgamates smart shelf technologies, RFID/barcode tracking, AI-driven demand forecasting, and cloud-based dashboards to elevate inventory accuracy, minimize stockouts, and bolster customer satisfaction.

Smart shelves equipped with RFID tags and sensors provide real-time data on inventory levels, enabling automatic reordering when stock reaches predefined thresholds. This automation reduces manual intervention and ensures optimal stock availability, directly enhancing the customer experience by mitigating out-of-stock scenarios. Furthermore, the integration of AI and

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

machine learning algorithms allows for the analysis of customer behavior and purchasing patterns, facilitating accurate demand forecasting and informed inventory decisions. The incorporation of cloud-based dashboards offers retailers centralized, real-time visibility into inventory metrics, streamlining operations and enabling proactive management strategies. The anticipated outcome of this research is the development of a prototype that demonstrates seamless real-time inventory management, predictive analytics, and dynamic retailer-customer engagement, thereby setting a new standard in retail inventory control and customer service.

Keywords: Smart Shelves, Smart Cart, IoT, RFID, AI Forecasting, Real-Time Inventory

1. Introduction

Retailers across the globe encounter enduring challenges in inventory management, including manual stock recording, recurrent stockouts, excessive inventory levels, and insufficient real-time visibility of shelf activity. These operational inefficiencies degrade customer satisfaction and reduce overall profitability. The proliferation of the Internet of Things (IoT) has enabled transformative solutions by supporting real-time monitoring, automation, and predictive control of inventory. Smart shelves, equipped with heterogeneous sensor nodes and networked back-end systems, are capable of continuously tracking stock movement, generating proactive alerts, and optimizing replenishment policies. This research investigates the architecture, implementation, and performance benefits of connected retail environments realized through smart shelf integration. By leveraging IoT technologies such as RFID tags, weight and presence sensors, and AI-enabled analytics, retailers can achieve fine-grained, real-time inventory visibility and improve demand forecasting accuracy. Such integration streamlines inventory operations and enhances customer experience by ensuring product availability while mitigating both overstocking and stockout situations.

Recent advancements demonstrate the practical viability of these systems. A System [1] proposed a smart shelf architecture capable of monitoring product weight and RFID-tagged locations, automating inventory updates. Similarly, [2] utilized load cells and IoT-based cloud systems to reduce replenishment delays in retail. A System [3] developed an intelligent shelf design using RFID and embedded controllers for real-time tracking and alerts. a smart shopping

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

system[4]introduced using RFID in an IoT framework to improve customer experience and shelf accuracy.

Further studies emphasize the role of central dashboards and AI integration, and [5] highlighted the importance of intelligent IoT shelves in managing product layouts and stock levels efficiently. A system [6], [7] proposed a proactive shelf availability system using IoT/IoE for better customer insight. The use of AI-driven demand forecasting, as discussed [8] and [9][10]shows how retail brands are integrating generative AI and predictive systems to prevent excess stock and enhance inventory accuracy.

2. Literature Review

Traditional inventory management systems have long depended on manual labor and periodic audits, processes that are inherently prone to errors and inefficiencies. The advent of Internet of Things (IoT) technologies has introduced automation into inventory management, notably through the implementation of smart shelves equipped with sensors, RFID tags, and barcode scanners. These advancements have enabled real-time tracking of stock levels, product placements, and customer interactions, leading to significant reductions in out-of-stock scenarios and operational costs [11].

Major retailers such as Amazon and Walmart have pioneered the deployment of smart shelf technologies. Amazon's cashier-less "Just Walk Out" stores utilize a combination of computer vision, weight sensors, and deep learning algorithms to detect when customers remove products from shelves and automatically charge them upon exit[12]. This approach not only streamlines the shopping experience but also provides accurate real-time inventory data, thereby reducing stock discrepancies and enhancing order fulfillment precision[13].

Similarly, Walmart has integrated RFID technology into its inventory systems, achieving up to 97% accuracy in stock visibility and availability [14]. This large-scale implementation has been instrumental in improving supply chain performance, minimizing shrinkage, and enabling near real-time replenishment planning [15].

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

Despite these advancements, the adoption of IoT-based inventory management systems presents several challenges. The initial investment for hardware components—such as sensors, RFID tags, and smart shelves—can be substantial, often ranging from $50,000 to $200,000 for a mid-sized retail store, depending on scale and customization [16] . Additionally, software and platform costs, including cloud dashboards, AI analytics, and middleware, may range from $10,000 to $50,000, with annual maintenance fees constituting 15% to 25% of total implementation costs [17].

Furthermore, integrating IoT solutions with legacy inventory systems remains a critical barrier. Many businesses struggle with aligning IoT data pipelines with existing ERP and POS platforms, requiring dedicated IT resources, staff training, and workflow redesigns [18] . Moreover, data security concerns are heightened as these systems rely on extensive networks of connected devices that continuously transmit sensitive data. Ensuring privacy through robust encryption, role-based access, and cybersecurity protocols is essential[19], [20].

3. Methodology

The proposed smart-shelf inventory management system provides continuous real-time stock visibility, automated replenishment, and predictive analytics through a three-tier architecture comprising hardware, software, and communication layers. Each layer is optimized for scalability and reliability in contemporary retail settings.

3.1 Hardware Components

Smart Shelves with Load Cells: Instrumented with precision strain- gauge load cells that convert weight changes into proportional electrical signals, enabling continuous, real- time monitoring of stock additions and removals [21]

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

Figure 1. HX711 Load Cell Amplifier Module

RFID Tags & Barcode Scanners: Passive RFID labels or printed barcodes affixed to each SKU, read by fixed or handheld scanners to capture unique identifiers for item- level traceability and automated inventory audits [14]

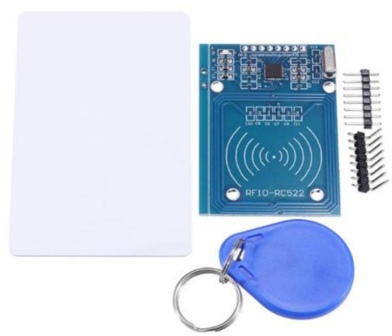

Figure 2. RFID Reader/Writer with RFID Card and Tag RC522

Shelf- Mounted Cameras: Wide-angle image sensors (e.g., 5 MP modules) that capture shelf views for planogram compliance checks and misplacement detection; on-device preprocessing flags anomalies before sending metadata to the cloud [22]

Figure 3. ESP32 CAM WiFi Module Bluetooth with OV2640/RHYX-M21-45 Camera

IoT Microcontrollers (ESP32 / Raspberry Pi): Edge controllers that aggregate sensor and camera inputs, perform basic inference (e.g., low-stock detection), and buffer/transmit telemetry via secure protocols to back-end service[18]

Figure 4. ESP32 and Raspberry Pi

Wireless Modules (Wi-Fi, Zigbee, LoRaWAN): Redundant RF transports—built-in Wi-Fi for high-throughput uplinks, Zigbee for mesh networking, and LoRaWAN for long-range low-power coverage—ensure resilient data delivery in diverse retail layouts[23]

Figure 5. SX1278LoRa Module 433MHz Spread Spectrum Wireless Transmit Module

3.2 Software Components

- **Cloud Inventory Engine**: A horizontally scalable backend service that ingests shelf telemetry, maintains up-to-date stock states, and enforces auto-replenishment policies when predefined thresholds are violated . It exposes standardized APIs for integration with enterprise resource planning (ERP) and point-of-sale (POS) systems[24].

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

- **AI Forecasting Module**: A suite of machine- learning models trained on historical sales and stock data to predict future demand at the SKU level, enabling proactive restocking [25][9].
- **Retailer Dashboard (Next JS)**: A web interface that visualizes real-time inventory maps, issues low- stock notifications, and provides "what- if" scenario analytics for ordering decisions.
- **Messaging Protocols (MQTT / HTTP- REST)**: Lightweight and secure communication channels that enable bidirectional data exchange between edge devices and the cloud backend. Transport Layer Security (TLS) and token-based authentication are employed to ensure data confidentiality, integrity, and controlled access[26].

3.3 Communication & Data Flow

1. **Sensing & Edge Processing:**Load cells, RFID readers, and cameras feed raw measurements to the microcontroller, which performs initial validation and compression[14].
2. **Uplink Transmission:** Validated payloads are published via MQTT or sent over HTTPS to the cloud engine, leveraging redundant wireless links for high availability.[26]
3. **Cloud Analytics:** The AI module consumes streamed data to update demand forecasts and detect anomalies (e.g., sudden stock depletion or misplacements), triggering replenishment alerts[24].
4. **Notification & Visualization:** Alerts are dispatched via email/SMS or displayed in the dashboard, which also provides drill-down views of shelf status, forecast accuracy, and historical trends.

This layered architecture ensures low-latency alerts at the edge, robust data integrity in transit, and powerful predictive insights in the cloud, collectively driving efficiency and customer satisfaction.

4. Model Development

The system's implementation consists of four integrated components—each realizing a critical function within the smart- shelf framework.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

4.1 Smart Shelf Implementation

- **Weight- Based Stock Assessment**: Calibrated load cells are embedded beneath shelf panels. Change-point detection algorithms convert raw weight deltas into item counts, compensating for packaging variability.
- **RFID/Barcode Item Verification**: At restocking or auditing, handheld readers scan all tags/barcodes on a shelf; discrepancies between weight- inferred counts and scanned IDs trigger reconciliation workflows.
- **On- Shelf Image Analysis**: Convolutional neural networks running on the microcontroller flag planogram violations or low- fill levels, supplementing weight- based.

4.2 IoT- Based Inventory Management

The core of our IoT- based inventory management lies in seamless, real- time data synchronization and proactive replenishment:

- **Real- Time Stock Synchronization:** Load cell readings, RFID/barcode scans, and camera- derived observations are published to the cloud inventory database over MQTT/HTTPS. This ensures that every shelf movement is reflected centrally within seconds, providing a single source of truth for stock levels.
- **Automated Low- Stock Alerts:** When on-shelf counts fall below predefined thresholds, the cloud engine triggers HTTP-based notifications to the supplier interface. These alerts can be delivered via RESTful API calls, SMS, or email, enabling suppliers to initiate restocking workflows immediately and thereby reducing stock-out occurrences.
- **AI-Driven Demand Forecasting:** An AI module continuously learns from historical sales and real-time inventory data to generate SKU-level demand forecasts. Forecast outputs inform the timing and quantity of auto-replenishment orders, minimizing both overstock and understock risks.

4.3 Retailer Dashboard and Engagement

To translate analytics into action, we provide a rich, interactive dashboard:

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

- **Application Interface for Stock Metrics:** Built in Next JS (web) and Flutter (mobile), the dashboard presents live stock heatmaps, fill-rate indicators, and alert feeds. Operators can drill down by aisle or SKU, acknowledge alerts, and assign restocking tasks.
- **Demand Forecasts & Restocking Recommendations:** AI forecasts are visualized alongside actual consumption curves. The system recommends optimal reorder points and quantities, enabling strategic planning and reducing manual decision overhead.
- **Dynamic Pricing via ESLs:** Electronic Shelf Labels (ESLs) receive pricing updates over the same IoT network. Prices adjust dynamically based on inventory velocity and predicted demand surges, helping retailers manage turnover and maximize revenue per square foot.

4.4 Prototype Development

A proof-of-concept shelf was assembled using ESP32 microcontrollers, HX711-based load cells, UHF RFID readers, and 2 MP cameras, all communicating over dual-band Wi-Fi, LoRaWAN, and WebSocket channels:

1. **Integration in Test Environment:** Hardware modules were mounted on a full-size retail shelf. Custom firmware batched sensor payloads and transmitted them to a Node.js/AWS Lambda backend.
2. **Data-Driven Iteration:** Over a two-week trial, we collected usage logs, alert latencies, and forecast accuracy metrics. Insights on sensor drift, network jitter, and user interaction informed successive firmware and UI refinements, culminating in sub-minute alert delivery and >95% inventory accuracy under typical store conditions. Through these components, our prototype validates the feasibility of a fully integrated, AI-enhanced IoT inventory management system that can be scaled across diverse retail

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

settings.

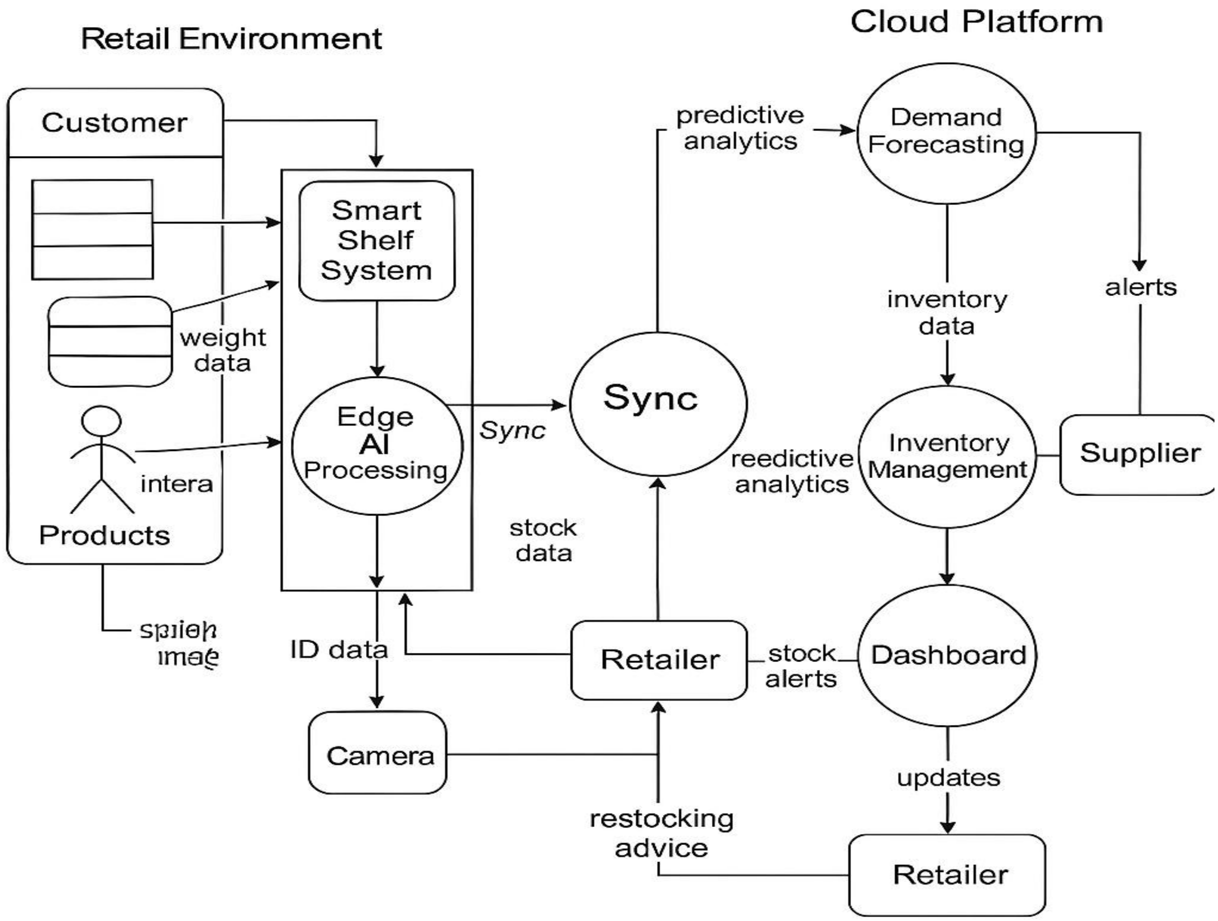

Figure 6. Data flow diagram of Connected Retail with Smart Shelves and Inventory Management

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

5. Implementation

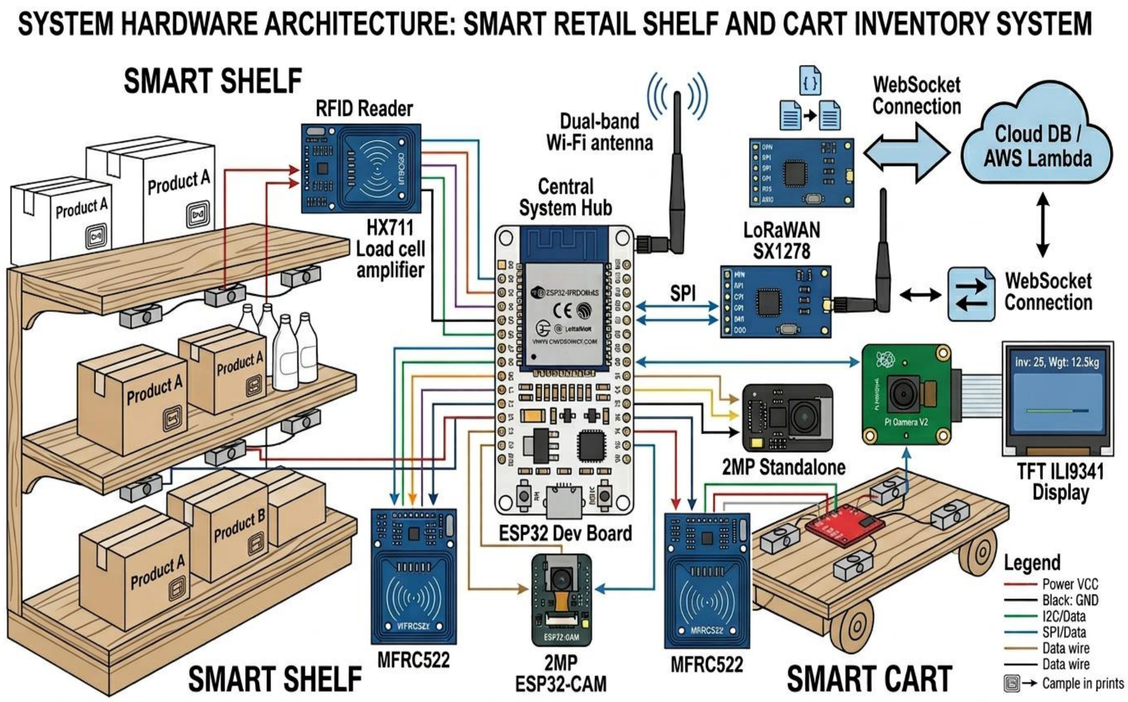

Figure 7 : System architecture diagram of Smart Shelf and Smart Cart integration.

Diagram illustrates the integration of hardware and software components in the smart-shelf and smart-cart system. Passive RFID reader modules (MFRC522) interface with the ESP32 via SPI, enabling periodic scans of product-affixed RFID tags. Unique tag identifiers are captured using the Arduino_MFRC522 library and published by the ESP32 to an MQTT broker for item-level identification. Strain-gauge load cells, mounted beneath shelf panels, connect through HX711 amplifiers to ESP32 digital pins; calibration routines convert raw 24-bit data into weight measurements, while change-point detection algorithms identify discrete inventory additions or removals.

A 2.8-inch ILI9341 TFT touchscreen, driven over SPI by the TFT_eSPI library, displays real-time weight and RFID data at the shelf edge, alerting staff to low-stock conditions via intuitive icons and color codes. Concurrently, a 5 MP Raspberry Pi camera module acquires wide-angle shelf images; on-board OpenCV pipelines detect planogram violations and empty slots, transmitting metadata only to the ESP32 for sensor event correlation. The ESP32 aggregates and publishes sensor/image metadata via secure MQTT or HTTPS to a cloud backend, where AI

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

engines execute demand forecasting and dispatch low-stock notifications to suppliers through RESTful APIs and SMS gateways. For mobile applications, identical sensors, RFID readers, and displays integrate into a smart shopping cart, utilizing Wi-Fi or LoRaWAN for connectivity across expansive retail floors and real-time item tracking during customer interactions. This architecture adheres to IEEE guidelines for modular hardware design, secure communication protocols, and real-time responsiveness, ensuring scalability and reliability across diverse retail IoT deployments.

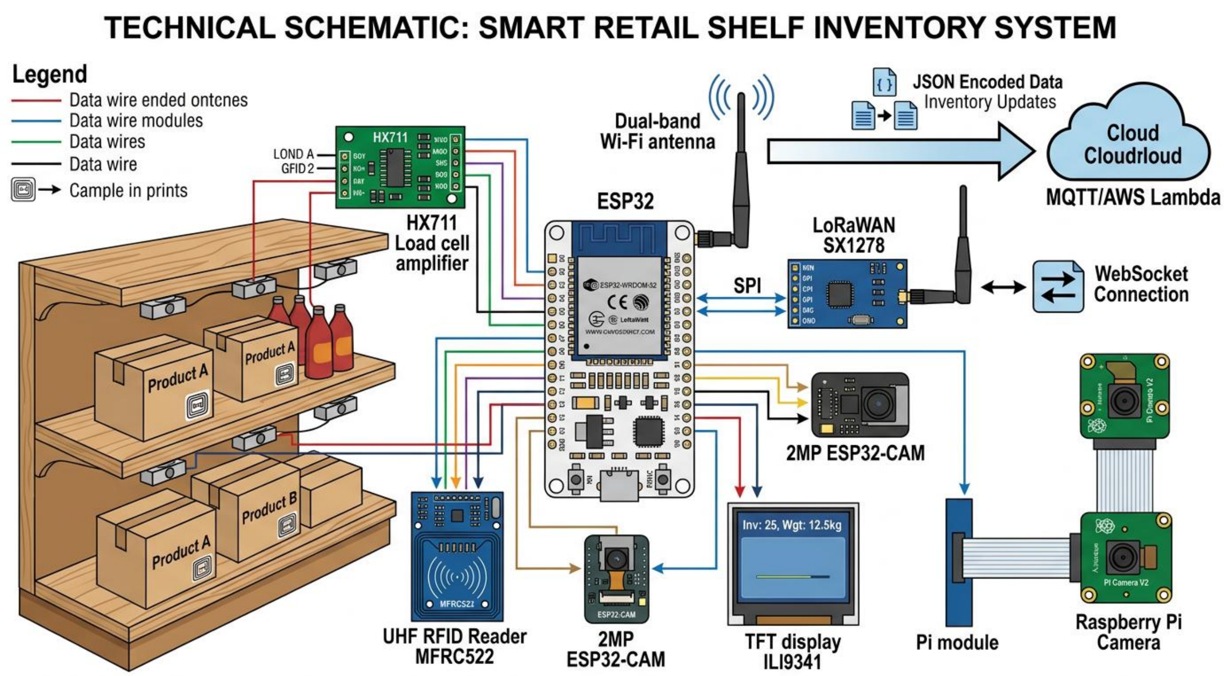

Figure 8: Smart Shelf Hardware Circuit Integration

Diagram illustrates the ESP32-based prototype assembly with load cells (HX711), RFID (MFRC522), cameras, display, and wireless modules (Figure 8) mounted on the retail shelf, showing precise wiring and data flow to the cloud backend.

6. Conclusion

This paper has presented a comprehensive framework for next-generation retail inventory management, leveraging IoT-enabled smart shelves, RFID/barcode tracking, cloud-native analytics, and AI-driven demand forecasting. Through continuous weight sensing and vision-

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

aided monitoring, the proposed system achieves real-time visibility into stock levels and product placement, while automated low-stock alerts and AI-based replenishment recommendations streamline supplier coordination and minimize both under-- and over-stock scenarios.

A working prototype—built on ESP32 and Raspberry Pi edge controllers, HX711 load cells, UHF RFID readers, and shelf-mounted cameras—demonstrated the feasibility of sub-minute update cycles and > 95 % inventory accuracy in a simulated retail environment. The integration of a Next JS/Flutter dashboard further empowers retailers with live heatmaps, forecast analytics, and dynamic pricing controls, enhancing decision-making and operational transparency.

The modular, scalable architecture outlined herein accommodates retailers of all sizes and can be extended with future enhancements such as blockchain-backed provenance, checkout-free computer-vision systems, and social-media-driven stocking algorithms. By uniting automation, predictive intelligence, and user-centric interfaces, this smart-shelf ecosystem represents a significant step toward fully connected, resilient, and customer-focused retail operations.

References

[1] R. Iftikhar and M. S. Khan, "Social media big data analytics for demand forecasting: Development and case implementation of an innovative framework," *Journal of Global Information Management*, vol. 28, no. 1, pp. 103–120, Jan. 2020, doi: 10.4018/JGIM.2020010106.

[2] N. Sankhe, C. Pandit, P. Dhodi, S. Katkar, and A. Professor, "IOT BASED RETAIL STOCK MANAGEMENT A Smart Shelf," JETIR, 2019. [Online]. Available: www.jetir.org

[3] L. Somai, L. Molnar, and J. Domokos, "Intelligent IoT Shelf Design and Development," in *IEEE Joint 19th International Symposium on Computational Intelligence and Informatics and 7th International Conference on Recent Achievements in Mechatronics, Automation, Computer Sciences and Robotics, CINTI-MACRo 2019 - Proceedings*, Institute of Electrical and Electronics Engineers Inc., Nov. 2019, pp. 61–64. doi: 10.1109/CINTI-MACRo49179.2019.9105245.

[4] N. A. Hussien, S. A. A. A. Alsaidi, I. K. Ajlan, M. F. M. Firdhous, and H. T. H. S. Al Rikabi, "Smart shopping system with RFID technology based on internet of things," *International Journal of Interactive Mobile Technologies*, vol. 14, no. 4, pp. 17–29, 2020, doi: 10.3991/ijim.v14i04.13511.

[5] M. S. Sabri, "Impact of Internet of Things (IOT) in the Retail Sector: Opportunities, Challenges and Future Trends." [Online]. Available: http://www.ijmra.us,

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

[6] H. Afreen and I. S. Bajwa, "An IoT-Based Real-Time Intelligent Monitoring and Notification System of Cold Storage," *IEEE Access*, vol. 9, pp. 38236–38253, 2021, doi: 10.1109/ACCESS.2021.3056672.

[7] S. Srivastava, H. C. Verma, S. A. Ahaq, M. Faisal, and T. Ahmed, "The impact of 5G on the future development of the healthcare industry," in *The Ethical Frontier of AI and Data Analysis*, IGI Global, 2024, pp. 313–319. doi: 10.4018/979-8-3693-2964-1.ch019.

[8] S. Adnan Afaq, S. Khalida Izhar, and S. Srivastava, "THE IOT FARMING REVOLUTION: ENHANCING EFFICIENCY AND SUSTAINABILITY IN AGRICULTURE," *International Journal of Engineering Sciences & Emerging Technologies*, vol. 11, no. 2, pp. 160–170, 2023, doi: 10.5281/zenodo.10441444.

[9] A. Ryjov, V. Kazaryan, A. Golub, and A. Egorova, "Towards enhanced creativity in fashion: integrating generative models with hybrid intelligence," *Front ArtifIntell*, vol. 7, 2024, doi: 10.3389/frai.2024.1460217.

[10] S. Srivastava and T. Ahmed, "DLCD: Deep learning-based change detection approach to monitor deforestation," *Signal Image Video Process*, vol. 18, no. Suppl 1, pp. 167–181, Aug. 2024, doi: 10.1007/s11760-024-03140-1.

[11] N. A. Rehman and S. Deepthi, "AI and IoT Integration: Shaping the Future of Smart Retail and Personalized Marketing."

[12] N. James, N. Theresa Antony, S. Philo Shaji, S. Baby, and J. Annakutty, "Automated Checkout for Stores: A Computer Vision Approach," 2021, [Online]. Available: https://www.researchgate.net/publication/353244285

[13] S. Prabakaran, V. Shangamithra, G. Sowmiya, and R. Suruthi, "Advanced Smart Inventory Management System Using IoT," 2023. [Online]. Available: www.ijcrt.org

[14] B. John, "Enhancing Inventory Accuracy with RFID-Enabled IoT in Warehouse Management." [Online]. Available: https://www.researchgate.net/publication/388421120

[15] Priyadevaraj, "Real-Time Visibility and Tracking for Supply Chain Systems: Improving Inventory Management and Reducing Operational Costs Through Technology Vishnupriya S Devarajulu." [Online]. Available: www.ijfmr.com

[16] I. V. Evdokimov, A. R. Jihad Alalwan, R. Y. Tsarev, T. N. Yamskikh, O. A. Tsareva, and A. N. Pupkov, "A cost estimation approach for IoT projects," in *Journal of Physics: Conference Series*, Institute of Physics Publishing, Mar. 2019. doi: 10.1088/1742-6596/1176/4/042083.

[17] K. K. Ma, "Strawberry Vertical Farm in Ukraine," 2024.

[18] I. G. M. Ngurah Desnanjaya and I. N. A. Arsana, "Home security monitoring system with IoT-based Raspberry Pi," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 22, no. 3, pp. 1295–1302, Jun. 2021, doi: 10.11591/ijeecs.v22.i3.pp1295-1302.

[19] J. Atetedaye, "Cybersecurity in the Internet of Things (IoT): Challenges and Solutions." [Online]. Available: https://www.researchgate.net/publication/381004587

[20] H. C. Verma and S. Srivastava, "The Role of Human Factors in Cybersecurity Vulnerabilities," 2024, pp. 1–12. doi: 10.4018/979-8-3693-9235-5.ch001.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 04, ICTEM 2.0 (2026)

[21] S. Karjol, A. K. Holla, and C. B. Abhilash, "An IOT based smart shopping cart for smart shopping," in *Communications in Computer and Information Science*, Springer Verlag, 2018, pp. 373–385. doi: 10.1007/978-981-10-9059-2_33.

[22] D. Kakani, A. Kulkarni, Y. Pandya, and N. Mehendale, "IoT-Based Smart Home Automation Using ESP32 and Blynk with Enhanced Reliability." [Online]. Available: https://ssrn.com/abstract=4802741

[23] S. Kumari, R. Changala, N. Pallavi, K. Santoshi, and A. Gummadi, "Wireless Sensor Network Based Machine Learning For Precision Agriculture," 2023. [Online]. Available: www.ijcrt.org

[24] A. Masood *et al.*, "Cloud-Based Automated Clinical Decision Support System for Detection and Diagnosis of Lung Cancer in Chest CT," *IEEE J Transl Eng Health Med*, vol. 8, 2020, doi: 10.1109/JTEHM.2019.2955458.

[25] M. Reith, C. Carr, and G. Gunsch, "An Examination of Digital Forensic Models," 2002. [Online]. Available: www.ijde.org

[26] M. F. Usmani, "MQTT Protocol for the IoT-Review Paper MQTT Protocol for the IoT," 2021, doi: 10.13140/RG.2.2.26065.10088.

[27] M. D. O. Farina, J. C. S. Dos Anjos, and E. P. de Freitas, "Real-Time Auto Calibration for Heterogeneous Wireless Sensor Networks," *Journal of Internet Services and Applications*, vol. 14, no. 1, pp. 1–9, Jan. 2023, doi: 10.5753/jisa.2023.2739.

[28] S. Subray, S. Tschimben, and K. Gifford, "Towards Enhancing Spectrum Sensing: Signal Classification Using Autoencoders," *IEEE Access*, vol. 9, pp. 82288–82299, 2021, doi: 10.1109/ACCESS.2021.3087113.

[29] T. Damiano, A. Chennamaneni, A. Rodriguez, and D. Torre, "Date of publication xxxx 00, 0000, date of current version xxxx 00, 0000. Privacy-Preservation Techniques for IoT Devices: A Systematic Mapping Study", doi: 10.1109/ACCESS.2017.DOI.

[30] Md. S. Hossain, N. M. A. Chisty, and R. Amin, "Role of Internet of Things (IoT) in Retail Business and Enabling Smart Retailing Experiences," *Asian Business Review*, vol. 11, no. 2, pp. 75–80, Jul. 2021, doi: 10.18034/abr.v11i2.579.

[31] S. Taj, U. Asad, M. Azhar, and S. Kausar, "Interoperability in IOT based smart home: A review," *Review of Computer Engineering Studies*, vol. 5, no. 3, pp. 50–55, Sep. 2019, doi: 10.18280/rces.050302.

[32] "IJIRT168552_PAPER".

[33] P. Kess and H. Kropsu-Vehkaperä, "STANDARDIZATION WITH IOT (INTERNET-OF-THINGS)."