



Research Paper

IoT-Based Smart Shopping Cart with RFID-Enabled Automated Billing System: A Literature Review of Recent Point of Sale Research

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Abstract

Smart shopping carts have emerged as an important Internet of Things (IoT) application for improving the efficiency of supermarket and retail-store operations. Conventional checkout systems depend on barcode scanning and centralized cashier counters, which can create queues, increase transaction time, and require repeated manual handling. Recent research has investigated RFID-enabled carts, IoT connectivity, mobile applications, computer vision, artificial intelligence, edge/cloud processing, automated invoicing, and digital payment integration. This literature review examines representative IEEE and IEEE-indexed research from 2015–2026, with emphasis on the most recent work relevant to an IoT-based smart shopping cart with RFID-enabled automated billing. The review compares system architectures, identification technologies, communication methods, billing mechanisms, security features, inventory functions, and intelligent capabilities. Early work established RFID/ZigBee-based centralized billing, while later studies integrated mobile applications, AIoT, computer vision, Raspberry Pi/ESP32 platforms, payment gateways, real-time analytics, and machine learning. Recent 2025–2026 studies indicate a transition from simple automated billing toward intelligent, connected retail platforms capable of real-time tracking, inventory forecasting, accessibility assistance, and personalized shopping. The review identifies remaining challenges including RFID collision and read reliability, tag cost, product removal detection, payment security, privacy, scalability, interoperability, and real-world evaluation. These findings provide a research foundation for designing a practical RFID-enabled IoT smart cart with automated billing.

Index Terms

Internet of Things (IoT), RFID, smart shopping cart, automated billing, intelligent retail, wireless communication, inventory management, embedded systems, artificial intelligence, digital payment.

Received 07 Oct., 2026; Revised 16 Oct., 2026; Accepted 18 Oct., 2026 © The author(s) 2026.

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I. Introduction

Retail shopping is increasingly influenced by connected devices, automation, and data-driven services. In conventional supermarkets, customers normally select products, carry them to a checkout counter, wait for scanning, and complete payment before leaving. Barcode-based identification requires the scanner to obtain a line-of-sight view of each product and generally involves one-item-at-a-time scanning. During peak shopping periods, this workflow can produce long queues and increase the workload of cashiers.

The Internet of Things provides a framework for connecting physical objects, sensors, embedded controllers, communication networks, databases, and user applications. In a smart shopping cart, RFID tags can provide machine-readable identities for products, while an RFID reader mounted on the cart can detect tagged items as they are added or removed. The cart controller can obtain product information from a local or cloud database, calculate the running bill, display the shopping list, and transmit transaction information to a store server. Such an architecture moves part of the checkout process from a fixed counter to the shopping cart itself.

The research direction has progressed considerably. Early RFID smart-cart systems focused primarily on automatic billing and wireless transmission. Later work introduced mobile applications, customer authentication, product-location assistance, and web-based supermarket management. AIoT research has

combined RFID with image processing and YOLO-based object detection. More recent systems have investigated payment gateways, Raspberry Pi and ESP32 platforms, automated invoicing, voice assistance, intelligent navigation, customer tracking, and machine-learning-based inventory forecasting.

This literature review therefore focuses on the evolution of smart shopping cart technology and identifies design principles useful for an IoT-based RFID automated billing system. Particular attention is given to recent IEEE publications because they provide a strong technical basis for a contemporary engineering project.

II. Review Methodology

The literature search emphasized IEEE Xplore records and IEEE-published conference/journal work concerning smart shopping carts, RFID-based billing, IoT retail automation, AI-enabled carts, and automated invoicing. Recent publications from 2024–2026 were prioritized, while influential earlier studies were retained to explain the evolution of the technology. Search terms included smart shopping cart, RFID smart cart, IoT-based shopping cart, automated billing, RFID retail, AIoT smart cart, intelligent shopping cart, and automated invoicing.

The selected studies were evaluated according to: (1) product-identification technology, (2) cart hardware and processing platform, (3) communication technology, (4) billing architecture, (5) customer interface, (6) inventory/security functions, (7) AI or computer-vision capability, and (8) limitations and research opportunities.

III. Evolution of RFID and Smart Shopping Cart Systems

The foundational concept of an RFID smart cart was to attach an RFID tag to every product and equip the cart with a reader. The cart identifies products during shopping and communicates the selected-product information to a billing server. Chandrasekar and Sangeetha proposed an RFID and ZigBee-based automatic billing architecture in which a product identification device containing a microcontroller, LCD, RFID reader, EEPROM, and ZigBee module was installed on the cart. Product data were stored locally and transmitted to a centralized billing system, thereby targeting reduction of checkout queues [1].

This architecture established several concepts that remain relevant: unique product identification, cart-level transaction storage, wireless communication, and centralized product-price databases. However, it relied on a relatively centralized infrastructure and did not provide the richer mobile, cloud, AI, and payment capabilities expected from modern IoT retail systems.

IV. IoT-Based RFID Smart Cart

Shahroz et al. presented an IoT-based smart shopping cart using RFID, Arduino, Bluetooth, and a mobile application [2]. The system extended automatic product identification by connecting the cart with customer-facing software. The reported architecture supported customer authentication, shopping-list functions, product searching, promotions, and RFID-based product selection. A web-based supermarket management system was also used for administrative functions.

The major contribution of this work is the integration of the physical shopping cart with an application and management platform. Instead of treating RFID as only a billing sensor, the system demonstrates how RFID data can support the complete shopping experience. This provides a useful architectural model for projects in which the cart communicates with a mobile device or IoT backend.

Nevertheless, Bluetooth-based connectivity and microcontroller-centric processing can limit scalability compared with modern Wi-Fi/edge architectures. The study also highlights an important practical consideration: the success of an RFID cart depends not only on software but on reliable tag placement, reader range, product orientation, and transaction-state management.

V. Decision-Tree and RFID Performance Research

Research on passive RFID smart carts has also investigated the performance of RFID identification itself. The IEEE study titled 'Increasing Passive RFID-Based Smart Shopping Cart Performance using Decision Tree' explored the use of a decision-tree approach for improving smart-cart performance [3]. This direction is important because RFID environments can generate uncertain or noisy observations when several tags are present simultaneously.

For a practical cart, the identification layer should distinguish between products being added, removed, or accidentally detected from nearby shelves. Thus, machine-learning methods can potentially complement RFID signal characteristics and cart-state information. However, algorithmic performance must be evaluated against realistic retail conditions rather than only laboratory demonstrations.

VI. AIoT-Based Smart Cart Systems

Sakthivel et al. proposed an AIoT-based smart cart system that combines RFID with image processing and object detection [4]. Rather than assigning a separate RFID tag to every individual product, the reported concept uses RFID cards for payment/customer interaction while grouping similar products and using YOLO-based object detection to determine the number of selected items. This hybrid approach addresses one of the practical limitations of large-scale RFID deployment: tagging every product individually can be costly and operationally burdensome.

The study is significant because it illustrates a shift from single-sensor automation toward multimodal perception. RFID provides identity or transaction information, while computer vision provides visual confirmation and quantity estimation. For future smart carts, combining RFID, weight sensing, and vision may improve reliability, especially for products that are difficult to tag or for detecting item removal.

VII. Raspberry Pi, Wireless Control, and RFID

An IEEE conference study investigated a fast and low-cost wireless-controlled smart shopping cart using Raspberry Pi and RFID technology [5]. The use of Raspberry Pi demonstrates the movement from simple microcontroller-only systems toward edge-capable computing platforms. A Raspberry Pi can support higher-level software, local databases, image processing, web interfaces, and wireless networking in addition to RFID acquisition.

The trade-off is increased power consumption, cost, and software complexity. Therefore, an engineering design should select the processing platform according to the required functions. A lightweight ESP32-class controller may be sufficient for RFID acquisition, display, and Wi-Fi communication, whereas Raspberry Pi-class hardware becomes more appropriate when local computer vision, advanced analytics, or a richer user interface is required.

VIII. IoT Smart Cart with Payment Gateway

A 2024 IEEE study titled 'IoT Based Smart Shopping Cart Integrated with Payment Gateway' investigated an IoT cart using a barcode reader, Raspberry Pi, Bluetooth, LCD, and server-based billing [6]. Although the identification method is barcode-based rather than RFID-based, the study is relevant to the billing architecture because it demonstrates the integration of the cart with automated server-side invoicing and payment processing.

The work shows that automated billing should be considered as an end-to-end transaction rather than merely a product-scanning function. A complete system requires customer identification, item recognition, cart-total calculation, bill generation, payment confirmation, and transaction closure. For an RFID-based project, the same transaction pipeline can be retained while replacing barcode acquisition with RFID.

IX. Recent IEEE Research: RFID-Powered Smart Cart

Recent IEEE research has continued to focus directly on RFID-powered smart carts. Matthew et al. reported 'RFID-Powered Smart Cart: Hassle-Free Shopping & Instant Billing' at the 2025 IEEE 1st International Conference on Innovations in Engineering and Next-Generation Technologies for Sustainability [7]. The work combines RFID, IoT, and embedded systems to automate item recognition and real-time billing. Its emphasis on instant billing demonstrates the continuing relevance of RFID as a direct alternative to conventional checkout scanning.

The importance of this work for current project design lies in the convergence of three layers: RFID-based physical identification, IoT connectivity, and automated transaction processing. This architecture is closely aligned with the proposed project topic and supports the use of an RFID reader, embedded controller, product database, wireless communication, and automatic invoice generation.

X. 2025 IEEE Smart Shopping Cart Using RFID

A 2025 IEEE conference publication, 'Smart Shopping Cart using RFID Technology for Automated Billing and Enhanced Retail Experience,' directly addresses automated RFID billing [8]. The title itself reflects the current research emphasis: RFID is no longer treated simply as an identification technology but as an enabling component of a broader retail-experience platform.

The recent research trend suggests that an effective smart cart should provide immediate feedback to the customer, maintain an accurate running bill, and reduce dependence on conventional checkout counters. These requirements make display/interface design, transaction-state handling, reliable RFID reading, and network availability important engineering considerations.

XI. 2026 IEEE Research: CartSense and Automated Invoicing

The 2026 IEEE conference paper 'CartSense: An Internet of Things-Powered Intelligent Shopping Cart with Automated Invoicing' represents a newer generation of connected cart systems [9]. The reported architecture uses ESP32 microcontrollers and RFID readers, with MQTT communication over Wi-Fi/BLE for real-time cart updates. It also includes a long-range RFID docking concept for session-based automated invoicing and a unique RFID/QR trolley identifier.

A particularly useful feature is voice feedback through a DFPlayer Mini, intended to improve accessibility, including support for visually impaired customers. Shared-cart functionality and docking detection further demonstrate how modern smart-cart systems are expanding beyond basic billing. The use of MQTT also illustrates an important IoT design pattern: lightweight publish/subscribe communication can connect carts with backend services while avoiding rigid point-to-point architectures.

For a student project, the CartSense direction suggests a practical modular architecture consisting of an ESP32, RFID reader, product database, MQTT/Wi-Fi layer, customer interface, billing service, and final checkout/docking verification. A simpler prototype can implement the same conceptual architecture with fewer modules.

XII. 2026 IEEE Research on Intelligent Shopping Carts

A 2026 IEEE ICSEDIS paper, 'A Microcontroller-based Intelligent Shopping Cart with Automated Navigation and Real-Time Billing,' combines autonomous movement with RFID-based billing and IoT integration [10]. The work reflects a broader trend in which smart carts are becoming mobile robotic platforms rather than passive trolleys. Automated navigation can reduce customer effort, while shopping-data collection can support store operations.

The combination of navigation and billing creates additional research challenges. Localization, obstacle avoidance, user-following, energy management, and safe motion must operate concurrently with reliable product identification. This suggests that the RFID billing subsystem should be designed as an independent, robust module that can operate even when navigation or other intelligent services are unavailable.

XIII. AI-Driven Smart Carts, Tracking, and Forecasting

Recent IEEE Access research has extended smart carts into AI-driven retail platforms. The paper 'AI-Driven Smart Shopping Carts With Real-Time Tracking and Inventory Forecasting for Enhanced Retail Efficiency' proposes an architecture integrating person-specific tracking, reinforcement learning for navigation, LSTM-based demand forecasting, POS integration, edge computing, and cloud processing [11].

This research marks a significant transition from automation to intelligence. The cart can potentially contribute data not only to the customer's bill but also to inventory planning, demand prediction, customer interaction, and store optimization. For an undergraduate project, the full AI architecture may be beyond the minimum implementation requirement, but its concepts provide strong directions for future enhancement.

XIV. Comparative Literature Analysis

Study	Year	Core Technology	Billing/Service	Major Contribution	Limitation/Gap
Chandrasekar & Sangeetha [1]	2015	RFID + ZigBee	Central billing	Early automated RFID billing architecture	Limited IoT/mobile intelligence
Shahroz et al. [2]	2020	RFID + Arduino + Bluetooth + App	Automated shopping/billing	Mobile application and supermarket management	Bluetooth-centric; practical RFID issues
Decision Tree study [3]	2020	Passive RFID + ML	Smart-cart performance	ML-assisted RFID performance	Requires realistic large-scale validation
Sakthivel et al. [4]	2022	RFID + Vision + YOLO	Automated billing/payment	Hybrid RFID-computer vision approach	Higher system complexity
Raspberry Pi + RFID study [5]	2022	Raspberry Pi + RFID	Wireless smart cart	Edge-capable cart platform	Power/cost and implementation complexity
Payment Gateway study [6]	2024	IoT + Barcode + Raspberry Pi	Server/payment gateway	End-to-end transaction concept	Barcode rather than RFID
Matthew et al. [7]	2025	RFID + IoT	Instant billing	Recent RFID-focused retail automation	Prototype-level evaluation
IEEE RFID Smart Cart [8]	2025	RFID + IoT	Automated billing	Directly targets enhanced retail experience	Further scalability evaluation needed
CartSense [9]	2026	ESP32 + RFID + MQTT	Automated invoicing	IoT messaging, docking, accessibility	More hardware/software integration

ICSEDIS intelligent cart [10]	2026	Microcontroller + RFID + IoT	Real-time billing	Adds autonomous navigation	Navigation increases system complexity
AI-driven IEEE Access [11]	2025	AI + Edge/Cloud + POS	Automated billing + forecasting	Tracking and inventory intelligence	High computational/system complexity

XV. Key Research Gaps

Despite substantial progress, several research gaps remain. First, RFID detection is not always equivalent to reliable transaction detection. A reader may detect a tag without knowing whether a customer intentionally added the product. Second, product removal must be handled accurately so that the running bill does not become inconsistent. Third, metallic packaging, liquids, tag orientation, reader antenna placement, and multiple simultaneous tags can affect read performance.

Another gap is security. A smart cart contains customer identity, shopping history, transaction details, and potentially payment information. Secure authentication, encrypted communication, access control, and protection against RFID cloning or unauthorized reads should therefore be considered. IoT systems also require resilience against network failures. A cart should ideally retain a local transaction state so that a temporary Wi-Fi outage does not erase the customer's bill.

Scalability is also important. A prototype with ten products is straightforward, but a real supermarket may contain thousands of product SKUs and hundreds of carts. The backend must support concurrent transactions, product-price updates, inventory synchronization, and reliable transaction closure. Finally, many published systems remain prototype-oriented; more real-world evaluations are required under realistic store layouts, customer movement, radio interference, and high-density product conditions.

XVI. Recommended Architecture for the Proposed Project

Based on the literature, a practical IoT-based RFID smart shopping cart can be organized into six layers. The sensing layer contains RFID tags and an RFID reader. The edge-control layer uses an ESP32, Arduino-class controller, or Raspberry Pi depending on complexity. The communication layer uses Wi-Fi/BLE and optionally MQTT. The application layer maintains the cart session, product list, running total, and customer interface. The backend layer stores product, price, stock, customer, and transaction information. The transaction layer generates the final invoice and supports digital payment or cashier verification.

A suitable workflow is: customer authentication → cart-session creation → RFID product detection → product database lookup → add/remove validation → running-total update → display/app notification → inventory update → final bill generation → payment confirmation → transaction closure. This architecture directly incorporates the most reusable concepts found across the reviewed literature.

XVII. Conclusion

The literature demonstrates a clear evolution of smart shopping carts from simple RFID-based automatic billing devices to connected and intelligent retail platforms. Early RFID/ZigBee systems established automatic identification and centralized billing. IoT-based systems added mobile applications and management platforms, while AIoT research introduced computer vision and machine learning. Recent IEEE work has emphasized instant RFID billing, MQTT-enabled connected carts, ESP32 platforms, automated invoicing, accessibility, autonomous navigation, real-time tracking, and inventory forecasting.

For an IoT-based smart shopping cart with RFID-enabled automated billing, RFID remains an effective core technology because it enables non-line-of-sight product identification and can reduce manual scanning. However, reliable implementation requires more than an RFID reader. Product add/remove logic, transaction management, wireless communication, database synchronization, user feedback, security, and final payment verification must be integrated as one system. The most promising future direction is a hybrid architecture that combines RFID with weight sensing or computer vision, edge processing, secure IoT communication, and intelligent inventory analytics.

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Appendix A – Literature Search Notes

The review prioritizes recent IEEE publications available through IEEE Xplore or records identifying IEEE as the publisher. Some 2026 records are conference publications and may have limited publicly visible metadata. Bibliographic details should be cross-checked against the final IEEE Xplore record before submission to a university repository or journal.