STM JOURNALS

Journal of
Semiconductor Devices and Circuits

ISSN: 2455-3379
Volume 12, Issue 3, 2025
September–December
DOI (Journal): 10.37591/JoSDC

https://journals.stmjournals.com/josdc

Research JoSDC

RFID Based Smart Trolley Billing System Using IoT

Manikandan S.*, Harish Murugan A., Kamal S., Udhayakumar S., Yokesh D.

Abstract

Customers experience better retail interactions while operations become more efficient in the modernizing retail industry. Shopping through traditional methods requires lengthy manual scanning for products and billing operations leading retailers to require automation solutions for streamlining these processes. This system consists of RFID detection alongside 8051 microcontroller processing and load cells monitoring and uses IoT communications and relay controls to power an intelligent automated shopping cart. Real-time data tracking functions alongside cloud service readiness to deliver advanced monitoring and management capabilities as the system's standout feature. A Smart Trolley consumes RFID technology to recognize goods that go inside the cart through unique product tags linked with RFID. Product details that the 8051 microcontroller retrieves are displayed through an LCD screen interface. The IoT module (utilizing ESP8266 or ESP32) along with a load cell tracks product weight to send data about names and combined weight and cost Segue to the cloud where real-time monitoring takes place. The system utilizes a relay to execute weight-related functions including the detection of theft events. The system includes a switch that controls both the beginning and termination of the purchasing sequence. The system delivers automated operations together with precise product tracking along with weight measurement functionality and billing support. Data transmission to the cloud enables distant storage functions along with distant system monitoring that produces meaningful information about trolley utilization while bolstering inventory handling capabilities. The system allows product tracking and billing automation and IoT integration for data management which enables its deployment into multiple retail settings to deliver enhanced customer service alongside operational efficiency.

Keywords: Smart trolley, RFID technology, 8051 microcontroller, load cell, IoT communication, automated shopping

INTRODUCTION

The retail sector has experienced rapid improvements in technology over the past years to improve both efficiency and customer experiences alongside automatic process operations [1]. The intelligent IoT-powered Smart Trolley brings together current technologies to provide customers and shopkeepers with simplified and automated shopping operations. The Smart Trolley employs RFID (Radio Frequency Identification) alongside load cells and microcontrollers and cloud computing as well as IoT to execute automatic functions which combine product recognition with weight measurements and cost computation and distant monitoring capabilities [2]. Current shopping trolleys undergo substantial electronic updates yet maintain manual systems for item tracking and checkout transactions. Traditional checkout processes operate at a slow pace with frequent errors and create longer lines at customer service points. The Smart Trolley addresses shopping challenges by combining RFID for identifying items as well as load cells for weight detection which enables tracking specific merchandise live and enhances billing precision and improves trolley content management [3]. Robotics

***Author for Correspondence**
Manikandan S.
E-mail: mailingtomani@gmail.com

Student, Department of Electronics & Telecommunication Engineering, Karpagam College of Engineering Coimbatore, Tamil Nadu, India

Received Date: March 27, 2025
Accepted Date: July 07, 2025
Published Date: August 26, 2025

Citation: Manikandan S., Harish Murugan A., Kamal S., Udhayakumar S., Yokesh D. RFID Based Smart Trolley Billing System Using IoT. Journal of Semiconductor Devices and Circuits. 2025; 12(3): 1–8p.

systems built with IoT technology also perform cloud-based data transfers to identify three key pieces of information consisting of total cost and total weight and product listings [4]. Data transmission across networks enables real-time analytics and better inventory management services while delivering improved customer experience [5]. The system operates through the 8051 microcontroller that acts as the vital component responsible for retrieving sensor data and directing component operation (including weight measurement relay activation) and external system communications. The system features an integrated switch providing simple start-stop functionality and displays real-time product data alongside purchase costs and weight measurements through an LCD interface. This initiative seeks to develop an intelligent shopping cart which combines speed and convenience with theft prevention and remote IoT monitoring and modern cloud integration capabilities. The system project seeks to build technology which delivers superior client experiences throughout retail operations [6].

Traditional retail stores rely on human-operated product scanning along with weight measurements that result in extended lines at checkout points and human errors as well as operational inefficiencies. The issues negatively impact consumer satisfaction levels as they also decrease retail operational efficiency. Real-time tracking automation and preventive theft methods are hindered by the current system infrastructure when managing inventories. The Smart Trolley addresses shopping problems through RFID and IoT and load cells together with microcontrollers. This innovative system provides automated product recognition and precise weight measurements together with real-time billing and instantaneous cloud platform data integration capabilities. The Smart Trolley automation system boosts retail operations through improved shopping interfaces along with better inventory tracking functions which produces actionable data for retailer decision support. This research aims to create automated systems that use RFID and load cells and IoT to enhance product identification and weight measurement for real-time billing which raises both customer service and store efficiency.

- To design a Smart Trolley system that automates the process of product identification using RFID.
- To accurately measure the weight of items using load cells and display the information on an LCD screen.
- To provide real-time information about the trolley's contents, total weight, and cost through an IoT module.
- To enable remote monitoring and control through cloud integration.
- To integrate a switch that controls the start and end of the purchase process, triggering the sending of product details to the cloud.

LITERATURE REVIEW

RFID-enabled smart carts have been developed by Chandrasekar *et al*. using real-time track and which added up the merchandise of the customers' bills as soon as the items were placed on the cart [7]. According to Devi *et al*., their Smart Shopping Cart System automatically performed product scans through RFID and weight sensors before displaying real-time cost and weight details [8]. The research showed how merging smart sensors with wireless networking systems creates an uninterrupted shopping experience. Research has focused on IoT integration with shopping carts that provides real-time product data monitoring and inventory oversight through cloud systems. The IoT system designed by Shahroz *et al*. combined smart-cart technology to deliver informative product statistics and live transaction feedback while handling inventory operations [9]. RFID and load cells and the IoT demonstrate remarkable potential to modernize retail automation systems. According to Garg *et al*., UHF RFID systems yield essential benefits through their extended detection capabilities which expedite product recognition operations [10]. A passive RFID-based shopping system led by Yao and Carlson showed automatic item identification and billing along with real-time inventory updates while highlighting the need for cloud integration to achieve efficient data synchronization for inventory management [11].

Load Cells for Weight Measurement

Smart system weight measurement is not complete without load cells. Considering smart trolleys, they are a good opportunity to find an accurate method for weight measurement of products placed in the trolley. Asri *et al.* examined the method and the application of load cell and HX711 amplifier in an automatic system for measuring the weight of products in a smart grocery trolley [12]. It highlights the significance of weighing accurately and described how to do so with the help of the HX711 amplifier when converting signal from the load cell to microcontrollers of 8051 or Arduino.

IoT Integration in Retail Systems

IoT enables connecting sensors and communication systems i.e., Wi-Fi, Bluetooth to give insights about buying trends, stock, and billing. Kucuk *et al*. elaborated the way IoT shopping carts can transmit real-time data to cloud systems like ThingSpeak or Firebase [13]. It allowed for monitoring shopping details like list of products, its price and weight from a distant location, solve issues such as thefts, control their stocks and serve their clients better.

Theft Detection in Smart Trolleys

Security of assets from theft is a significant concern in the retailing domain, and implementation of theft detection mechanisms for smart trolleys is an emerging trend of study. In similar context, Alessa *et al*. introduced smart shopping system by employing RFID and sensors for measuring weight and actuality of items in the cart [14]. They wanted the system to produce an alarm or a message if any item was taken by the customers without being checked or weighed.

Cloud Computing for Data Storage and Analytics

Cloud computing has grown to be an important component for storing and analyzing data in current systems. Municipal smart shopping has been integrated by Khan *et al*. through cloud-based data analytics [15].

In retail environments, the current support systems mainly employ conventional approaches for recognizing goods and points of check, employing barcodes and manual handling of products' weight, respectively. RFID-based systems are already considered for automating product identification in some of the stores but it is not well implemented on the shopping carts [16]. In most existing smart trolley systems, the product identification, weighing, and billing are performed in different processes which consume much time and may mistake. Most systems are not equipped with instantaneous control of inventory or thefts. Some IoT applications involving trolleys have been piloted in some experiments but the technology is yet to be scaled up plus put into the dynamic shopping context. Some of the drawbacks in the existing system include integration, cost, and accuracy.

METHODOLOGY

Smart Trolley integrates RFID, load cell IoT and cloud computing technology for providing the smart shopping and retail management system. The trolley will incorporate RFID enabled product identification system for identification of the products. Load cells will weigh products and display the information in actual time. An LCD display will show the total cost and weight. A switch will allow users to start and complete their purchases. The system will also include theft detection mechanisms based on weight discrepancies and RFID scans. Through IoT, the system will send real-time data to the cloud, enabling remote monitoring and analytics for store owners. Combined, these technologies will increase customer satisfaction, decrease human mistakes, and enhance the efficiency of store management. All in all, the system will make the smart trolley solution a smart, efficient and integrated one that can be easily scaled. Additionally, Figure 1 shows the flow chart of the working model.

The proposed Smart Trolley System integrates RFID, IoT, and sensors to streamline the shopping process. Each product is tagged with an RFID, allowing the trolley's RFID reader to automatically detect items added or removed. Push buttons enable key functionalities: starting the purchase, removing items, and finalizing the bill. A load cell ensures security by detecting unauthorized actions, such as adding

items without scanning. An LCD displays product details and the running total in real time, while a buzzer alerts users to errors or unauthorized actions. Once the billing button is pressed, the total amount and purchase details are uploaded to the cloud via the ESP8266 Wi-Fi module for real-time synchronization. This system eliminates manual scanning, reduces checkout time, and provides enhanced security and convenience, making the shopping experience more efficient and user-friendly. Moreover, Figure 2 shows the block diagram of proposed system.

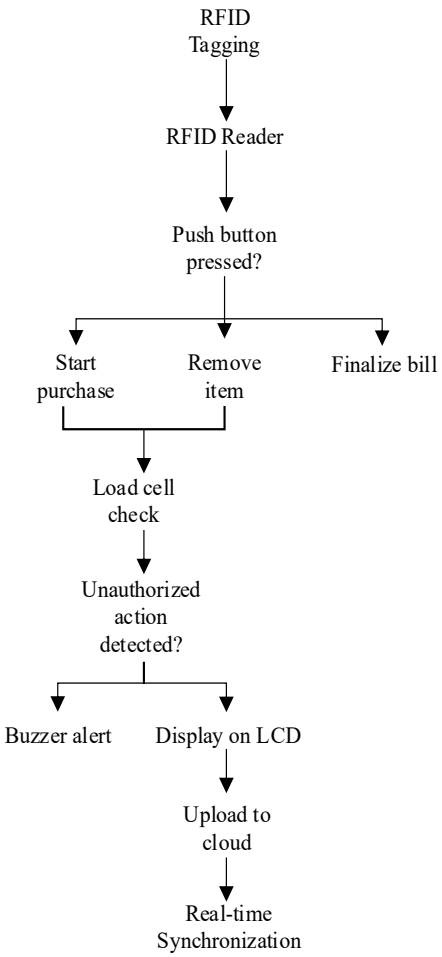


Figure 1. Flow diagram.

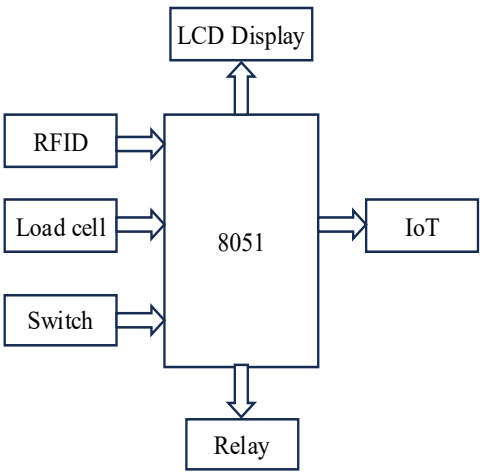


Figure 2. Block Diagram.

The block diagram depicts a microcontroller-based setup that uses the 8051 microcontroller and integrates RFID, a load cell, a switch, a relay, an LCD display, and IoT connectivity for purposes such as smart weighing systems, inventory management, or automated billing applications. The RFID module is used for identifying the products, where the RFID tags are scanned and the data is sent to the 8051 microcontroller for processing. The load cell measures weight and sends the data to the microcontroller for further processing and display on the LCD monitor and sends data to cloud. Smart weighing systems, inventory management or automated billing applications are some of the possible applications of such systems.

A switch is provided for manual input, enabling the user to control the operations of the system and trigger specific functions within the said system. The microcontroller ought to control the relay switches allowing electrical devices to be turned on/off on any particular conditions. This is useful for automation and smart control systems. The IoT module allows remote monitoring and data access via the internet, providing users with the capability to receive real-time information and control the system remotely. An LCD is a man-machine interface where basic data like weight value, authentication status, or system alerts can be displayed. Systems of this kind can be deployed in industries, smart homes, or security-based applications.

RESULTS AND DISCUSSION

The Smart Trolley System is an ingenious shopping cart automation system built around an 8051 microcontroller to promote the convenience and effectiveness of the user. The controller acts as the main component of the entire system by controlling inputs, processing the information, and coordinating other peripherals like the LCD display, push buttons, load cell, relay, and IoT module.

In the long run, this will eliminate laborious manual work in billing and cart management. The push buttons are located on the right side of the system: to add or remove an item, pressing the respective button any time reflects on the cart, and this updates the status and LCD display by the microcontroller. The load cell is used for measuring the weight of the items, and the microcontroller calculates and updates the cost for the users in real-time.

The LCD gives the user an interface whereby it shows relevant product detail regarding prices and total amount of charge. Every time a user adds or removes some item from the cart, the display is updated immediately so that people are informed in real-time. The Relay ultimately does the checkout automatically; its IoT connectivity allows for remote monitoring and data access. The system is a useful way of developing retail, supermarkets, and keeping record for inventory management systems.

It enhances shopping experiences through automation of billing, which reduces waiting times and eliminates human errors. It will also support advanced integration with RFID and barcode scanners that add leverage. Smart Trolley System makes shopping easier through cart automation, increases the satisfaction of consumers and a streamlined billing process. With efficient design and seamless integration of components, it presents a bright solution for the future of the retail sector and stock management.

The proposed model of 8051-Based Smart Trolley using IoT helps eliminate critical drawbacks in the conventional retail systems with the incorporation of RFID, load cell, and IoT. This system helps in easy identification of products, in accurate weighing of the products as well as in billing; since most of the time is cut down, all this improves the customer satisfaction as well as the overall flow of the business. Its real-time data transmission and cloud integration offer retailers valuable insights into inventory management and customer behavior while reducing human error in manual processes. Also, the theft detection mechanism enhances the efficiency of the system, labeling it as a contemporary solution for retail business.

The reliance on RFID technology may become problematic in areas with high levels of signal interference and measurements taken by load cell may be influenced by improper positioning of an item. However, convincing scalar and high performance in large real-estate environments with a lot of customer traffic still presents interesting questions to how IoT networks function and will function in the future as well as any network latency and security issues that may occur. However, the system has the following practical realizations: Convenient and faster shopping experiences, and benefits decision making to retailers. It may be possible to enhance the current work by embedding machine learning algorithms in order to employ sophisticated theft detection, looking into other types of communication such as BLE or NFC in order to address challenges with RFID technology, and performing large-scale real-life studies to determine the potential of current and new future scenarios in retail settings. Such improvements would therefore go further in underlining the Smart Trolley as a key enabler of retail automation innovation. Additionally, Figure 3 shows the hardware kit.

Smart Trolley Login Page

Figure 4 shows the interface of a Smart Trolley Admin Login page. It consists of a login form with the username and password fields and a button labeled "Admin Login" to access the system. The background shows a shopping environment with a trolley and barcode scanner, which makes it applicable for retail. The footer contains a copyright notice for the year 2025. This page appears to be a part of an IoT-enabled shopping cart system that offers administrative control for monitoring or managing operations. Figure 4 shows the login page of the smart trolley.

Product Details Dashboard

This image represents the Smart Trolley Dashboard that displays product details for a specific trolley (Trolley No. 1001). The columns include S.no., product name, quantity, and amount in Rupees (Rs). This interface enables the admins to view items in the trolley along with their respective quantities and associated costs. On the left sidebar, navigation options are available as "Dashboard" and "Product Detail". It gives a real-time track and management of the shopping data and, therefore, improves the efficiency of the smart retail solution. Figure 5 shows the product details dashboard.

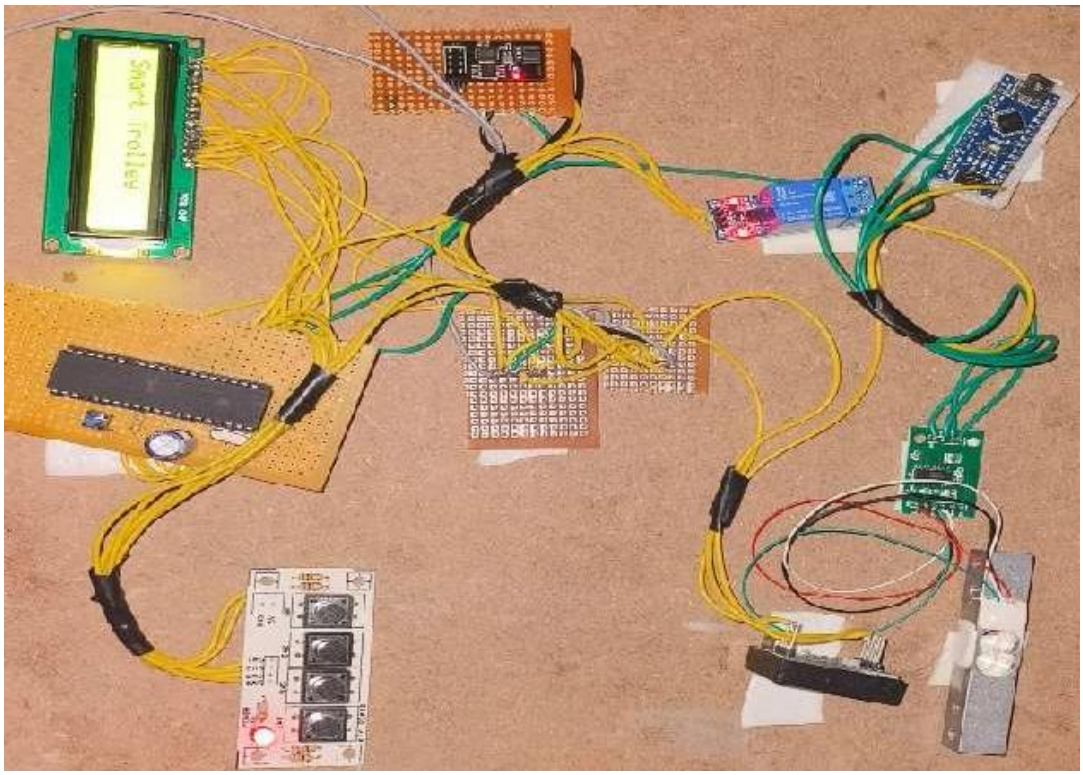


Figure 3. Hardware kit.

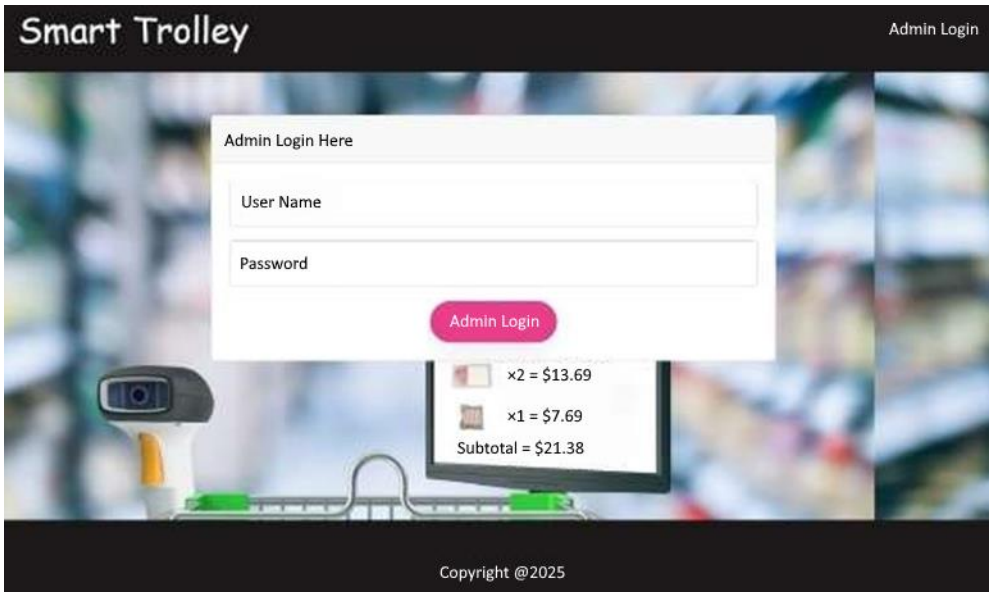
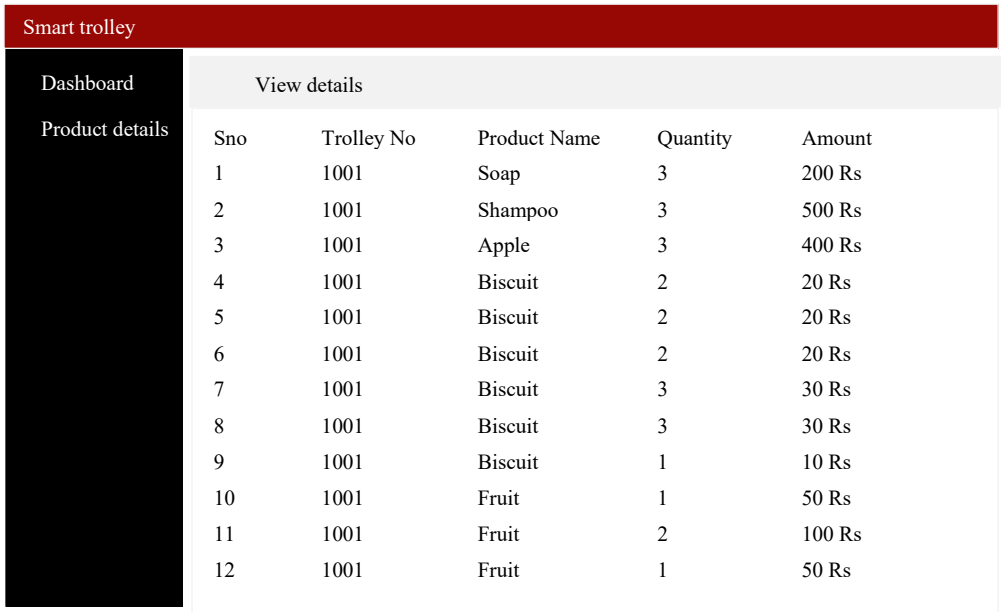


Figure 4. Smart trolly login page.



Sno	Trolley No	Product Name	Quantity	Amount
1	1001	Soap	3	200 Rs
2	1001	Shampoo	3	500 Rs
3	1001	Apple	3	400 Rs
4	1001	Biscuit	2	20 Rs
5	1001	Biscuit	2	20 Rs
6	1001	Biscuit	2	20 Rs
7	1001	Biscuit	3	30 Rs
8	1001	Biscuit	3	30 Rs
9	1001	Biscuit	1	10 Rs
10	1001	Fruit	1	50 Rs
11	1001	Fruit	2	100 Rs
12	1001	Fruit	1	50 Rs

Figure 5. Product details dashboard.

CONCLUSION

Smart Trolley showcases a new advancement in retail shopping and checking from RFID, load cell, IoT and cloud computing technology for trolley as a technique to automate the process in shopping. It also gets rid of scanning, zero human error and more comfort to the customer while making billing real time and quick in operations. IoT with the common features of the layered structure of smart cities in the future to interconnect systems permits remote and live monitoring of various physical consumers: These insights would help in tracking inventories, sales performance, and customers, etc. Moreover, the system contains characteristics such as theft detection that increases store security even further. In general, this Smart Trolley system is capable of meeting all the existing needs that can simultaneously benefit a customer and a retailer by providing valuable data and better control over the shopping centers' operations. The prospects of the applications created thanks to the system are that retails environments can be made scalable and automatic as needed in order to make shopping more effective, safe and grounded on the data provided.

However, there are several directions of further development and improvement of the system which can be further researched. Among those is the use of machine learning algorithms providing more complex capabilities including, for example, theft prediction and adaptive stock regulation. They could monitor how users engaged with applications and fence-post, and identify suspicious activities, thus improving on security, and productivity. On the same note, researching for other technologies in relaying information like Bluetooth Low Energy (BLE), Near-Field Communication (NFC), or Ultra-Wideband (UWB) probably unveils challenges that RFID has, for instance, signal interferences, and restricted range.

REFERENCES

1. Reinartz W, Wiegand N, Imschloss M. The impact of digital transformation on the retailing value chain. Int J Res Mark. 2019 Sep 1; 36(3): 350–66.
2. Koroniotis N, Moustafa N, Schiliro F, Gauravaram P, Janicke H. A holistic review of cybersecurity and reliability perspectives in smart airports. IEEE Access. 2020 Nov 9; 8: 209802–34.
3. Baziyad H, Kayvanfar V, Kinra A. The Internet of Things—an emerging paradigm to support the digitalization of future supply chains. In: The digital supply chain. Elsevier; 2022. p. 61–76.
4. Ponis ST, Efthymiou OK. Cloud and IoT applications in material handling automation and intralogistics. Logistics. 2020 Sep 21; 4(3): 22.
5. George CM, Menon S, Babu SL. The synergy of 5G and IoT integration for optimizing supply chains. In: Blockchain-Based Solutions for Accessibility in Smart Cities. IGI Global; 2024. p. 303–34.
6. Zhang Q, Qu M, Liu X, Cui Y, Hu H, Li Q, Jin M, Xian J, Nie Z, Zhang C. Three-in-one portable electronic sensory system based on low-impedance laser-induced graphene on-skin electrode sensors for electrophysiological signal monitoring. Adv Mater Interfaces. 2023 Jan; 10(3): 2201735.
7. Chandrasekar P, Sangeetha T. Smart shopping cart with automatic billing system through RFID and ZigBee. In IEEE International Conference on Information Communication and Embedded Systems (ICICES2014). 2014 Feb 27; 1–4.
8. Devi KG, Kaarthik TA, Selvi NK, Nandhini K, Priya S. Smart shopping trolley using RFID based on IoT. Int J Innov Res Comput Commun Eng. 2017 Mar; 5(3): 5392–8.
9. Shahroz M, Mushtaq MF, Ahmad M, Ullah S, Mehmood A, Choi GS. IoT-based smart shopping cart using radio frequency identification. IEEE Access. 2020 Apr 8; 8: 68426–38.
10. Garg P, Joshi T, Bansal D. Design and development of RFID based smart shopping cart using Arduino. Int J Electron Commer Stud. 2022; 13(4): 1–3.
11. Yao AC, Carlson JG. The impact of real-time data communication on inventory management. Int J Prod Econ. 1999 Mar 1; 59(1–3): 213–9.
12. Asri S, Hidayat H, Husodo D, Pratiwi I, Pradnya IN, Hasanah U, Al-Qudhus AR. Arduino-Based Automatic Weighing Machine Design. In IOP Publishing; IOP Conf Ser: Earth Environ Sci. 2024 Aug 1; 1381(1): 012028.
13. Küçük K, Bayılmış C, Msongaleli DL. Designing real-time IoT system course: prototyping with cloud platforms, laboratory experiments and term project. Int J Electr Eng Educ. 2021 Jul; 58(3): 743–72.
14. Alessa TW, Alfarhan FA, Bugis FK, Aldawood AA, Alhuwaidi SA, Hussain AA. Smart shopping cart with machine learning, navigation, and weighing technologies. In 2024 IEEE 6th International Symposium on Advanced Electrical and Communication Technologies (ISAECT). 2024 Dec 3; 1–6.
15. Khan Z, Anjum A, Kiani SL. Cloud based big data analytics for smart future cities. In 2013 IEEE/ACM 6th International Conference on Utility and Cloud Computing. 2013 Dec 9; 381–386.
16. Kamble S, Meshram S, Thokal R, Gakre R. Developing a multitasking shopping trolley based on RFID technology. Int J Soft Comput Eng. 2014 Jan; 3(6): 179–83.

