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ORIGINAL RESEARCH ARTICLE

Fuel automata: Smart fuel dispenser using RFID technology and IoT-based monitoring for automotive applications

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ABSTRACT

In the modern era, time holds immense value, and individuals strive to avoid delays in their daily responsibilities. These fuel stations are time-consuming and rely on human labour for efficient operation. With each passing day, the number of vehicles and devices in our technologically advanced world continues to grow rapidly. As a result, customers wait in queues at fuel stations, fuelling their desire to transition to an automated fuel dispensing system and eliminate the manual fuel distribution process from their daily routines. This research paper introduces an innovative smart fuel dispenser system that leverages RFID technology and IoT-based monitoring to enhance automotive fuelling processes. By addressing the limitations of conventional fuelling systems, this proposed system provides a superior solution that is more efficient and effective. Notably, it offers numerous benefits, such as improved accuracy, efficiency, safety, and sustainability, thereby presenting potential cost savings for fuel station owners and operators. The ongoing project is focused on automating fuel dispensing stations using RFID technology as a highly efficient tool. This approach aims to reduce the traffic congestion typically seen in front of fuel stations by shortening the time required for fuel dispensing compared to traditional manual operations. To enhance control and monitoring capabilities, an Android application has been created. This app allows for the tracking of fuel transactions and transaction history for both customers and fuel station dealers. The system utilizes NodeMCU and the Android app as an Internet-of-Things platform for seamless communication between the system, customers, and dealers. This study presents concrete evidence that supports the viability and potential advantages of the proposed system, emphasizing its capacity to revolutionize the fuelling industry and mitigate carbon emissions. The findings derived from the implemented system have been thoroughly examined, offering an intelligent solution for a sustainable future.

Keywords: Automotive; Fuel Dispenser; Intelligence; Internet-of-Things; RFID

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1. Introduction

India is a galactic country with a population of more than 1.38 billion. Currently, the number of automobiles is growing at a very rapid rate. This results in a daily increase in fuel usage. Therefore, dispensing gasoline to each vehicle in these circumstances takes much time. Currently, everything is digital. Most gas stations in many current systems feature the main unit that handles operations such as negotiating the electrical pump, monitoring the flow, operating the display, and ultimately shutting off the pump. However, a person is still required to collect the money, and many human blunders are expected. Fuel distribution to many vehicles at the fuel stations has incepted umpteen complications in India. The petrol stations we are using are time-consuming and require a human workforce. The vehicle driver must wage for fuel with cash or online defrayal; it's time-consuming. To place petrol stations in an out-of-town area is very costly. In a normal petrol station, there is a high chance of fuel robbery, and also there would be high traffic overcrowding. All these problems are solved by using an unmanned (automated) petrol station, which requires less time to run and is impressive and can be installed anywhere. The customer person going to utilize the service has to do the payment by using a system, that is electronic clearing system. In this proposed fuel automation system, we use the Radio Frequency Identification (RFID) card to fill Petrol/Diesel at the fuel station. These systems are less time-consuming, highly reliable, and efficient.

The production and distribution of various petroleum products are cautiously handled. These needs are met by cutting-edge technology, which also serves as the foundation for developing conjunctive interaction. Thus, an automated or uncrewed gas station utilizing global systems for mobile communication is an example of a new technology that serves as the foundation for the security of product distribution and dispersion and data-keeping using the system database. It is connected to one of the programming languages and personal computer (PC) ports. Even if most of today's fuel stations are automated or unmanned at the moment, there is room for a fully automated system to be put in place to offer authentic and cashless transactions. Petrol stations don't have phoney currency detector equipment. Additionally, robbery or theft is more likely due to the abundant cash available at the cash register. While dispensing the fuel, mistakes or misconduct are made. We can pay for the purchase with a credit or debit card, but we used to forget to bring it. It is necessary to alter the current system to prevent certain cognitive states and maintain a record of all interactions. Automating the current gasoline dispensing system is not tough to work with because we live in the 21st century, with sophisticated automation tools, machinery, and a digital environment.

The Internet of Things (IoT) originated from the occurrence of wireless technologies, micro-electro-mechanical systems, the Internet, and microservices. The convergence has helped take down the large walls between operational information technologies, allowing unregulated machine-generated data to be analyzed for visual percept that thrusts improvements. IoT gains its full potential by utilizing important role-playing objects, i.e., "smart" objects that use various electronics like sensors and actuators that can comprehend their context. Via built-in or inherent networking aptitude and capabilities, they could communicate with each other in every possible way, completely access the open-source internet networking services and interact with the whole human world. This not only makes the world widely connected but also comfortable and robust.

1.1 Literature review

Al-Rajaba *et al.*[1] focused on developing an Intelligent Location-Based Service System (ILBSS). This mobile application combines a payment application with a search and selection tool for gas stations. Their chosen system is a geographic information system, which uses the global positioning system to locate users with up to 90% accuracy and offers user-friendly information. They added a feature to the mobile application that allows users to choose the gas station the driver wishes to visit. Baqir *et al.*[2] applied graph theory and Dijkstra's algorithm to mobile applications, ILBSS, and spatial science (which can automatically find directions between physical locations, such as driving locations on Google Maps) and works on weighted graphs. The main benefit of this approach is that it allows users to locate nearby empty or not-too-congested gas stations. This system has a Security validation, which is one of its drawbacks. Implementing secure payment mechanisms and methods is necessary. The fundamental objective is to design a basic prototype of a smart or intelligent petrol pump based on RFID as a payment tool and control it remotely at a high-security level[2]. Nayal *et al.*[3] focused on reducing wait times, clearing up common misunderstandings, resolving disputes that come up at gas stations, and ensuring that the fuel being supplied is accurate. The project's primary goal is to use RFID technology to build a system capable of trustworthily deducting the amount of gasoline provided from a user's registered card. The advantage of Nayal *et al.*[3] is that RFID technology ensures that the consumer receives the appropriate amount of fuel and that there should be no adulteration at the fuel station. According to Nayal *et al.*[3], the third advantage. Having automated self-service results in a reduction in the labour force. Fuel theft is prevented thanks to the usage of RFID technology. Accuracy in fuel dispensing. It contains precautions for customers regarding the low card balance for the effective working of the system.

Sheth *et al.*[4], the main objective is that some of these fuel stations wouldn't be open around the clock due to a lack of labour and environmental factors. With all of these considerations in mind, a mechatronics approach is made to build an autonomous fuel-filling system that would be effective, cost-effective, open 24/7, demand the least amount of labour, and fill fuel in the shortest amount of time. An automobile must be parked by the marker signals when parked in a parking space or bay. Sensors and controllers are used to control it. The proposed petrol station provides several benefits: It can operate around the clock in any setting and could help with labour savings. Theft and waste of fuel are seldom noticeable to determine whether the suggested system is cost-effective; all operations can be time-studied. For simplicity of use, automatic payment options can be implemented. Naveed *et al.*[5] proposed a low-cost automatic authentication and identification system that can be deployed to authenticate the user databases and track people all over the area. The interfacing of PC and software also accompanies the system, that is, database logging software for communication of serial ports with a microcontroller and a low-cost antenna is primarily designed to obtain a range of up to 10 cm by using passive RFID cards and tags. It has presented an RFID-based authentication middleware that effectively combines demand encryption of files and a protocol based on elliptic curve cryptography and also has proposed an authentication protocol based on Gen-2. Isolated from the PC interfacing and database logging, the proposed system approaches make a large amplitude carrier system to effectively detect the modulated response in the proximity of the RFID tags. In this paper, the system designed is of high effectiveness, reliability, and ease of maintenance of the RFID tags authentication and is a foremost general system that can be used anywhere at the point where the hallmark of persons and objects is required. It also aims to develop a low-cost antenna that usually achieves a sensational transmission range of more than 10 cm.

Saleh *et al.*[6] have suggested utilizing RFID to improve security. The author has also concentrated on user prevention and authentication of access to the workplace by unauthorized users, as well as designing a system with a high ability to safeguard information and system-based resources. The suggested solution mandates that the workstation be locked when the user leaves the computer unit. The approach utilized in this suggested system is a computer-structured network-based security system Workstation, which is founded on applying safeguards to users' access for only the resources and services that are eligible to be accessible. Saleh *et al.*[6] are more focused on the limitation portion. The lightweight directory access protocol, a directory service protocol that typically stores and provides information in a directory service, is used. According to Saleh *et al.*[6], the system's advantage is that it offers solutions for trust-related difficulties in these networks and serves as a convenient authentication service for some common tools like biometrics, software, etc. Pranto *et al.*[7] developed a concept for a system that can track a car's fuel filling amount, time, and cost while also informing the owner of the vehicle about the fill and refill. Here, the system is split into two sections: the first is a mobile application, and the second is a gas station. The users sign up for the system and manage their accounts via the mobile app. Each user has an RFID that functions much like a prepaid card. Any authorized recharging location can be used to recharge the card. After scanning the RFID card and supplying each person with a different password, the fuel would be automatically deducted from the pump for each person.

Kumar *et al.*[8] worked on developing software, hardware, and transmission infrastructure and authorized the authentication of every vehicle. Vehicular Cloud Computing (VCC) mainly offers real-time computational facilities to vehicles equipped with low computing devices to modify travel time and confront accidents and traffic congestion. The main method used for developing the idea is RFID and VCC, a best-selling technology to deal with the unique identification of the object. Vehicles are attached to RFID-based vehicular ad-hoc networks to collect user information. For providing security to the user-authenticated key, agreement protocols are used. The RFID-assisted system mainly contains cloud servers, readers, and tags. Three types of RFID tags include: passive, semi-active, and active. Users use passive tags for identification in the system of communication. Initially, the reader sends information to the tag. Kumar *et al.*[8] mainly focused on creating a mathematical solution for authentication and validation by using simulation tools. The system provides security and also mainly benefits from low-cost and unmanned identification. This system improves the user experience, provides greater security, and protects against repeat attacks. The disadvantage of this approach is that communication cost is very high because the usage of wireless communication is done through wide-open space, it is less secure, and transmission speed is also less. Chenna *et al.*[9] are creating privacy-preserving authentication to safeguard the security of RFID technology. In addition to protecting against desynchronizing and tracking threats, this protocol mandates scalability with $O(log\,n)$ search complexity. The author proposes a safe authentication procedure using a cloud-based database as an RFID server. The primary mechanism is an RFID reader, a backend server, and wirelessly connected tags from an insecure route. So, the data sent from the RFID tag to the RFID reader and from the RFID reader to the server is accessible to the general public and can be intercepted. The drawback of this strategy is that the algorithm's complexity is $O(log\,n)$, which results in poor time complexity. Kai *et al.*[10] proposed a cloud-based reciprocal authentication protocol that aims to ensure effective privacy preservation on the Internet of Vehicles (IoV) system, allowing people to travel intelligently and effectively while safeguarding their secrecy from disclosure, that the obscurity of the tag is implemented not only protects the privacy data of the service providers but also prevents the malicious tracking from outside and inside attackers. Cyber-Physical Systems (CPSs) are widely used in industry to allow functionality previously unachievable and process optimization. In IoV, the related CPS is also employed to promote trip mode effectiveness, and the system's internal security access control and private secrecy concerns are justly crucial. IoT is the main application that the author discusses in this study. High availability, which is one of the fundamental features of information security, cannot be assured through cryptography.

Kondaveeti *et al.*[11] mainly focused on prototyping with Arduino. Also worked on the idea of uploading a script to the electrically erasable programmable read-only memory of the Arduino board, which would then run without the board being connected to computers or other software outside the Arduino system due to its independence, portability, and a high degree of precision. An epitome converts theories into requirements for a practical, functional system. Here, the imagined ideas are conceptualized and built into a clear framework. Next, a rough set of clickable screens are created, one of which can be navigated by the user or developer to simulate interaction. Finally, high-definition screens with a code-like paradigm are used, and the project is eventually operational in real codes. Alsaify *et al.*[12] proposed an authentication and hallmark protocol based on observing the system's transmissions between tags and readers. The proposed authentication scheme by the author is based on inserting decoys within the exchanged communications (between RFID readers and tags) and is used in the authentication process. Moreover, the proposed authentication scheme is mathematically modelled and validated using extended simulation. Accordingly, from the point of view of Alsaify *et al.*[12], a husky, robust and unequivocal authentication scheme that fits both limited resources and security requirements and demands of passive RFID tags is required. This work proposes a robust yet resource-alert authentication scheme for passive RFID tags and their readers, videlicet, and decoy-based authentication. Authentication can be achieved using advanced cryptographic techniques and devices with abundant processing power. The enrollment process of the RFID authentication system is a very important methodology used by the author. Li *et al.*[13] proposed a safe, cost-conscious data storage space plan based on blockchain that maximizes cache data placement and avoids tampering. This strategy employs the quantum particle swarm optimization method to address the placement of the data cache problem with the most contented caching benefit while keeping transmission cost and edge hoard size constraints in mind. The trust issue between sellers, purchasers, and causal agent nodes is expected to be resolved by a blockchain-based secure redistributed data trade model, which is also expected to boost user incentives for data commerce. A safe cost-alert data caching algorithm based on blockchain is being designed. It helps minimize communication delay, reduce the cost of data storage space, and ensure data security in the data caching process.

The RFID classification, tags, current applications, disadvantages, and limitations are briefly introduced in different literature[14–16]. This paper evaluates technologies' current improvement, evolution, and future scope. This technology uses an automatic data seizure system which aids in increasing system efficiency and functionality and is applied in many more brand-new ways. In this paper, the system projected is an auto-ID technology that uses barcode, magnetic stripe, IC card, voice recognition, fingerprint, optic character recognition and optical stripe, etc., which are also personal identity technologies. The researchers say that court-ordered metrology conducts field surveillance of fuel distributors to verify the proper operation of these measuring units[17–20]. In these papers, a distributed and decentralized approach is suggested. They employed IoT-based car meters to estimate and quantify the amount of fuel in refuelling tanks. Additionally, they have employed blockchain technology to prevent collusion attacks and offer a truly distributed and decentralized surveillance solution that implements and uses statistical-analytical surveillance analyses as smart contracts. They used the platform's Hyperledger fabric level for this experiment, which used Byzantine fault-unbigoted consensus. We can locate tampered fuel dispensers with specificity and sensitivity above 95% in a hypothetical scenario where vehicular meters have error rates of less than 5% and every vehicle refuels an average of 10 times every fill-up. A blockchain can digitally record any type of data or asset, including self-executing documents frequently referred to and defined as smart contracts.

Al-Naima *et al.*[21] have implemented the RFID-based fuel station at oil products distribution company in Baghdad, and it uses an ELA816B RFID reader with its passive tags. However, IoT-based controlling and monitoring are not available. Baqir and Motlak[2] have introduced ESP8266 and RFID tags for fuel station automation. The authors have done a front-end system, and the backend software for controlling and monitoring was not carried out. Abbas *et al.*[22] have suggested Raspberry Pi, RFID, and web server for toll gate automation. The authors have used multiple programming languages to obtain desired output, such as HTML, Python, PHP, SQL, and CSS. In addition to that, it uses various tools, including the Raspberry Pi imager, Putty, and VNC viewer. Abdulla *et al.*[23] have introduced IoT-based electronic toll gate automation systems. The system comprises Arduino Yun, an ELA RFID module, an ultrasonic sensor, a servo drive, and a Liquid-Crystal Display (LCD). However, the authors have demonstrated the prototype, and real-time implementation has not been done. As per the literature study, it is found that IoT plays a major role in most engineering and science fields. Some of the applications of IoT technology are as follows. Khan *et al.*[24] have introduced an energy management scheme for the IoT system for smart irrigation systems, in which the evolutionary algorithms are used to select optimal cluster heads, energy regulations, and routing paths. Sarker *et al.*[25] have presented an extensive review of IoT security intelligence. This study gives a thorough overview of IoT security intelligence based on machine and deep learning techniques that conclude from unstructured data to defend IoT devices from a range of cyberattacks proactively. Almalavi *et al.*[26] have introduced an IoT system for air pollution prognosis and monitoring using a hybrid artificial intelligence algorithm. The air quality index is established using a gradient-boosted decision tree model, support vector regression, and linear regression. Irshad *et al.*[27] have introduced an IoT-based thermoelectric air management system for smart construction applications. The performance of a thermoelectric air-cooling system intelligently managed by an IoT-based design is examined in this research for a practical tropical climate application.

1.2 Research gaps

The concepts in the study of Al-Rajaba *et al.*[1] lack payment security and don't work on the chances of duplicate payments. This paper might have worked on fire safety grounds since there's a possibility of fire attacks by using mobile phones inside petrol stations. For the system to function effectively, greater effort should have been put into alerting customers via SMS or email when their accounts are empty. Only video analysis and hybrid systems were covered in the research of Baqir and Motlak[2]. Thus, researchers can concentrate on obtaining secure high-level data in their upcoming studies. Knowledge for creating intelligent gas pumps that users can use to save time. Additionally, it features a better performance that is dependable and secure. Nayal *et al.*[3] have used an Arduino IDE, and the system does not understand the AVR microcontroller. No debugger is included for checking scripts, sketches, and shields; it is not easy to modify.

Sheth *et al.*[4] have used old technology and didn't use RFID technology; it is time-consuming and cannot be adopted by most people. This method can be adopted only in new cars and cannot be seen in old cars. Naveed *et al.*[5] lack the duplication and cloning of tags. This might have worked on improvements to increase the range of the tag used in the reader. Further improvement can be done by using a method in which the tag encrypts the ID and sends it to the reader, eliminating the capturing of RFID.

In the study of Saleh *et al.*[6], RFID does not combine conventional or logical security to provide access security. As elementary stimulation must be used to illustrate the proposal and assess the key components, this does not impact the system's overall performance or add more head parts elements like data quantity, speed, and distance. The concepts in the study of Pranto *et al.*[7] lack better control and management with the high cost of RFID system implementation and deployment cost, believing that manufacturers may lead this diffusion. Hence, suitable techniques are designed using efficient methods to make the automated system more economical, user-friendly, and honest. Kumar *et al.*[8] mainly worked on modelling the system using a statistical approach. It's quite a lengthy process to understand and can't able to implement for another system. This process may lead to data leakage and cyber threats. Furthermore, the ECC algorithm is more complex and difficult to implement than RSA encryption, which increases the likelihood of implementation errors, thereby reducing the security of the algorithm.

The concepts in the study of Chenna *et al.*[9] lack the theoretical benefits of the algorithmic approach, and determining the complexity of an algorithm is time-consuming because of the requirement for mathematical expression. Difficulty shows branching and looping in algorithms; understanding complex logic through these algorithms can be difficult. Kai *et al.*[10] lack when the addition of cryptographic techniques in the information processing leads to delay. Using public-key cryptography requires setting up and maintaining public key infrastructure, requiring a handsome financial budget. The security of cryptographic techniques is based on the computational difficulty of mathematical problems. Any breakthrough in solving such mathematical problems increases computing power. Kondaveeti *et al.*[11] didn't work on the limited processing power of the Arduino since the alternatives can work better than this, which leads to wastage. The primary flaw of the system is its lack of memory and storage space. Need work to complete activities like scheduling and database storage. Alsaify *et al.*[12] ignore the effect of exogenous variables on the operation. Statistical errors are ignored, and the authors didn't concentrate much on the statistical errors. They did not say how to improve the efficiency of the dummy data for RFID tags and RFID reader authentication.

The concepts in the study of Li *et al.*[13] have got a high latency issue. Privacy leakage was one more huge drawback. Payment disputes were unsolved leading to the discrepancy. Transmission delay has to be solved for the efficient working of the system. The concept proposed by Prakash *et al.*[14] lacks the global standardization process of RFID, an important issue different manufacturers have implemented in different ways. Researchers have to look into its various limitations and explore many alternate RFID technologies in the future that open new doors to make organizations; companies considered more secure, reliable, and accurate. It becomes challenging in this circumstance because a malicious vendor may activate and deactivate an electronic fraud on a fuel dispenser according to a timetable[15]. When we contrast a centralized system with a blockchain, although it is clear that the second performs better, readability is the key argument in favour of using blockchains in this system.

From the above discussions, it is found that traditional fuelling systems in the automotive industry are often inefficient and prone to errors, creating a need for more innovative and efficient fuelling solutions. This study proposes a smart fuel dispenser system using RFID technology and IoT-based monitoring that offers a more efficient and effective solution to the challenges facing traditional fuelling systems, with potential cost savings for fuel station owners and operators. The proposed system offers significant advantages over traditional fuelling systems by integrating RFID technology and IoT-based monitoring into fuel dispensers, including increased accuracy, efficiency, safety, and environmental sustainability. This research contributes to the field of automotive engineering and technology by proposing an innovative solution to the challenges facing traditional fuelling systems, with the potential to extend the proposed system to other industries beyond the automotive sector. This study is very important for several reasons:

1) **Efficiency:** Using RFID technology and IoT-based monitoring in fuel dispensing systems can significantly increase the efficiency of fuelling

operations. This can lead to faster refuelling times and reduced waiting times for customers.

2) **Accuracy:** Traditional fuel dispensers rely on manual input to record fuelling transactions. This can lead to errors and inaccuracies in the recorded data. RFID technology and IoT-based monitoring can help to automate this process and ensure that the recorded data is accurate and reliable.

3) **Safety:** Fuelling operations can be hazardous, and any errors or malfunctions in the fuelling system can result in accidents or other safety hazards. Using smart fuel dispensers with RFID technology and IoT-based monitoring can help reduce the risk of accidents and improve overall safety in fuelling operations.

4) **Environmental impact:** The use of smart fuel dispensers can also help to reduce the environmental impact of fuelling operations. By accurately measuring fuel consumption, fuel wastage can be minimized, and emissions can be reduced.

Overall, this study has the potential to significantly impact the efficiency, accuracy, safety, and environmental impact of fuelling operations, which is of critical importance in the automotive industry. The following research questions enabled us to propose new technology for refuelling systems. (i) How can RFID technology be integrated into fuel dispensers to improve the accuracy of fuelling transactions? (ii) How can IoT-based monitoring be used to optimize fuelling operations and reduce customer waiting times? (iii) What are the potential safety benefits of using smart fuel dispensers with RFID technology and IoT-based monitoring? (iv) How can the use of smart fuel dispensers with RFID technology and IoT-based monitoring help to reduce the environmental impact of fuelling operations? (v) What are the challenges associated with implementing smart fuel dispensers with RFID technology and IoT-based monitoring in the automotive industry, and how can these challenges be addressed? These research questions would motivate our investigation into the development, implementation, and potential impact of a smart fuel dispenser system using RFID technology and IoT-based monitoring for automotive applications. After a thorough literature study and noticing all the cognitive states and conditions of the existing world, smart fuel dispensing system is proposed, and the primary objectives of this paper are as follows.

- To develop an auto-guided mechanism and to reduce human work.
- An unmanned petrol station is the main objective to fulfil the consumer requirement over a wide area.
- To implement the task sequentially using RFID technology without any interruption or delay.
- The person (customer) self-going to utilize the service has to do the payment by electronic clearing system, which can make humans safer from robbery, fraud, theft, and any other unwanted incidences by using plastic money.
- To reduce the traffic congestion due to delays in filling the fuel and manual or in-person money exchange.

The proposal of a smart fuel dispenser system using RFID technology and IoT-based monitoring for automotive applications is based on the need for increased efficiency, accuracy, safety, and environmental sustainability in fuelling operations. Traditional fuel dispensers often rely on manual input for fuelling transactions, which can result in errors, inaccuracies, and safety hazards. In addition, traditional fuelling systems are often not optimized for maximum efficiency, resulting in longer waiting times for customers. The proposed method of a smart fuel dispenser system using RFID technology and IoT-based monitoring addresses these issues by automating the fuelling process and integrating advanced monitoring capabilities. RFID technology automatically identifies and tracks vehicles, drivers, and fuel types, ensuring accurate and reliable fuelling transactions. IoT-based monitoring provides real-time data on fuel levels, dispenser functionality, and vehicle movements, optimizing fuelling operations for maximum efficiency. Overall, the proposed method of a smart fuel dispenser system using RFID technology and IoT-based monitoring is a logical and innovative solution to the challenges facing traditional fuelling systems. It has the potential to significantly improve the efficiency, accuracy, safety, and environmental sustainability of fuelling operations in the automotive industry.

The paper is organized as follows. Section 2 discusses the problem definition and proposed solution to the defined problem. Section 3 discusses the methodology, which includes software and hardware sections of the proposed concept. Section 4 discusses the results and further analysis. Section 5 discusses the challenges and drawbacks of the suggested concept. Section 6 concludes the paper.

2. Problem statement and defined solutions

This section of the paper discusses the problems identified from the literature study and briefly discusses the solutions for the defined problem.

2.1 Problem definitions

The foundation of modern civilization is petroleum. It is a priceless and unique creation of nature. Its formation took millions of years. Thus, the correct use of the resource is essential. Fuel stations are currently manually operated, with various controlling equipment carrying various functions. The present manual fuel stations devour more time and require a considerable workforce. The time the automated petrol station takes to complete the operation is less than that of a normal petrol station. Furthermore, it is inclined to malpractices. There is a higher possibility of human-initiated errors and misplays. And also, there is a higher probability of wastage of fuel while dispensing it. By complete analysis of actual performance with desired performance, the main problem in the existing petrol pump system is the lack of data storage of the user usage activity and no application for the user to register and use it. Nowadays, everything is machine-controlled or automated, but then there is a need to collect, store and update user information for future reference.

2.2 Solution to the defined problems

As a solution to the problems discussed earlier, in this paper, we have proposed the concept to lessen human work and develop an auto-guided performance and make a completely unmanned fuel station to fulfil the requirement of every consumer over the broad area and implement the task consecutively by using RFID application technology without any delay. Here the person (customer) self-going to utilize the service has to register their RFID card in the designed app and do the online recharge of the card, which can make humans safer from fraud, robbery, and other unwanted incidences by using duplicate money. Also, this project proposal reduces traffic congestion[21]. Hence, it is less time consuming. In the proposed concept, the service providers are responsible for maintaining the transaction report of all the user usage activity and storing this data of all the users safely while including the collection of data, storing of data, and updating of data every time the user uses it. The main methodology used in this concept is registering an RFID card in the designed mobile app and the backend process[2]. The flow chart illustrated in **Figure 1** explains the entire workflow of the concept. It has two important different flows, which are ultimately connected.

Flow (1) represents the operations and functions of the service provider: In **Figure 1**, the service provider is responsible for the mobile app development for the user to get registered for accessing the RFID tag by filling in all the user details and using it by recharging the card and also responsible for maintaining the service side database management system for collecting, storing, updating, maintaining and processing the user data in the form of transaction report in the designed app responsible for the mobile app development for the user to get registered for accessing the RFID tag by filling all the user details.

Flow (2) represents the operations and functions of the user: Initially, the user has to register successfully to access the card through the designed mobile app. Users can use the registered RFID card by recharging it in the same app. According to **Figure 1**, when the user's vehicle enters the automated petrol station, the RFID reader waits to get a tag by displaying the message "HELLO" and "WELCOME TO DSCE PETROL BUNK". Then the display shows "SELECT YOUR FUEL" by giving the options such as “A. PETROL”, “B. DIESEL”, and “C. CHARGING”. Once the user selects any one of the options, for example, if the user selects “A. PETROL”, petrol is selected for refuelling. The same has been applied to other fuels. Then it asks the user to “Scan your card”. Once the user scans the RFID tag, the RFID reader reads the card, so the user information is scanned and sent to the connected backend system, where the user details are stored as a transaction report. After scanning the card, the system asks the user to “ENTER PASSWORD”.

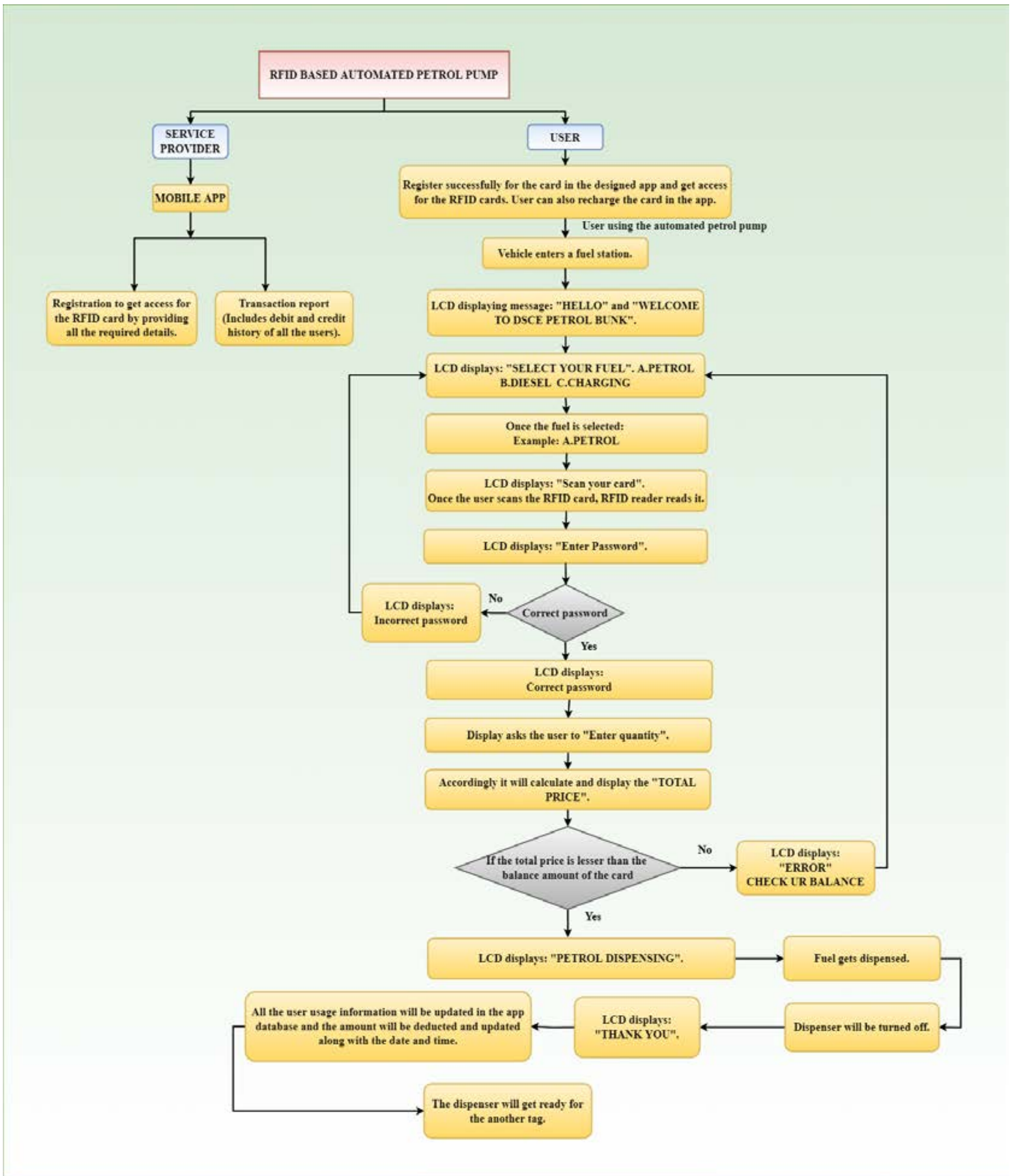


Figure 1. Workflow of the proposed automated petrol refuelling station.

If the user enters the incorrect password, the display shows “Incorrect password” and the system returns to the fuel step selection. Else, when the user enters the correct password, the display shows “Correct password” and asks the user to “Enter quantity”. To demonstrate the proposed concept, the fuel price of Rs. 100 INR is selected for 1 litre of fuel (Petrol or Diesel), and the system calculates the price for the entered quantity of fuel. Once the user enters the quantity of the fuel, the price is calculated using the above-mentioned standard value. If the total price calculated is greater than the balance amount of the card, the display shows “ER-

ROR, CHECK UR BALANCE". The price calculated is less than the card balance, then the display shows "PETROL DISPENSING" when the selected fuel is petrol. The display shows "DIESEL DISPENSING" if the selected fuel is diesel. Finally, after all these successful operations, the fuel gets dispensed. The dispenser is turned off and ready for another tag.

Similarly, when the user selects option "C. CHARGING", the display prints "Charging selected" and then asks the user to "Scan your card". Then the RFID operation begins. Then it follows the same procedure as that of petrol and diesel till the entering of quantity. For charging, 1 unit of electricity equals Rs. 10 INR. In operation, entering 1 as the quantity considers 10 units of electricity. Simultaneously units multiply for other quantities. For the price calculation, since 10 units are equal to Rs. 100 INR, the price is calculated for other quantities too. Then all the user usage information is updated in the app database, and the amount is deducted and updated with the date and time. The user and service provider can use the app and get all the users' debit and credit details with the date and time.

3. Methodology

Everything in the modern world is digital. Almost all petrol stations in active systems include a dominating controlling unit that handles a variety of responsibilities, including managing the electrical pump, imposing the display, measuring and computing the flow, and subsequently switching off the pump. However, numerous human mistakes are likely to occur since a person must gather the funds and collect the money. An RFID card is employed in this suggested automation system to access fuel at various fuel stations using the developed Android application for RFID card registration and card recharging. Simply place the RFID card close to the RFID reader whenever someone wishes to fill up their tank at the fuel station. The controller, i.e., the Arduino MEGA2560 board, then interprets the data from the RFID reader and takes the appropriate action as specified by the client. This automated fuel station technology offers users security while filling up at petrol stations by eliminating human interaction and lowering the risk of carrying cash every time. The primary technique comprises combining software and hardware operations. The main methodology includes the integration of hardware and software processes.

3.1 Hardware implementation

Figure 2 illustrates the block diagram of the proposed concept, in which Arduino MEGA2560 is used as the main controller, and it takes 5 V from the external power supply. There is a response exchange from NodeMCU to Arduino MEGA2560, whereas the external power supply also powers NodeMCU. RFID reader, i.e., MFRC522 powered by an external 5 V supply, scans the RFID cards and sends information to the controller. All the details sent by the controller are displayed in a 16 × 2 LCD powered by an external 5 V supply. The 4 × 4 keypad is important in performing and selecting the necessary actions. A dedicated relay driver is provided, which drives the charging port by supplying sufficient power. The voltage regulator LM7805 regulates a 12 V supply to 5 V. The driver ULN2003 is a motor driver for petrol and diesel pumps, which helps the pumps dispense the fuel.

Figure 3 illustrates the circuit diagram of the proposed concept. Arduino Mega 2560 contains 54 pins, of which 14 are (Pulse width modulation) PWM pins, 16 analogue input pins, and 4 UARTs (hardware serial ports) Analog input of Arduino MEGA is connected to the data pins of LCD. The NodeMCU is used for communicating between the main controller and the Android application through Wi-Fi communication protocol.

The following steps are used to code the main controller, the Arduino MEGA2560 controller. In addition, the flowchart of the entire programming flow is illustrated in **Figure 4**.

STEP 1: Initially need to include all the necessary libraries.

STEP 2: Then initialize the response indicator from NODEMCU to Arduino Mega (int res = 13).

STEP 3: Initialize all the necessary pins of various components like relay = A7, pump1 (petrol)

= 48, pump2 (diesel) = 49, delay = Z1, price = y.

STEP 4: Then LCD prints: "HELLO" and after some delay: "WELCOME TO DSCE PETROL BUNK".

STEP 5: LCD prints: "SELECT YOUR FUEL" after some delay LCD prints: by giving options: "A. PETROL", "B. DIESEL", and "C. CHARGING". If the user wants to select petrol, go to STEP 6, Diesel, go to STEP 10, Charging, go to STEP 13.

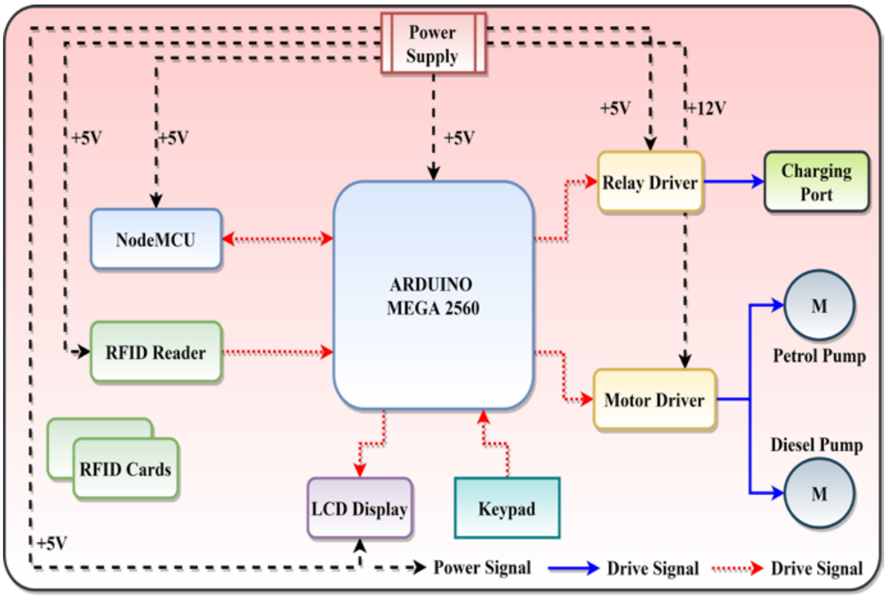


Figure 2. Block diagram of the proposed automated petrol station.

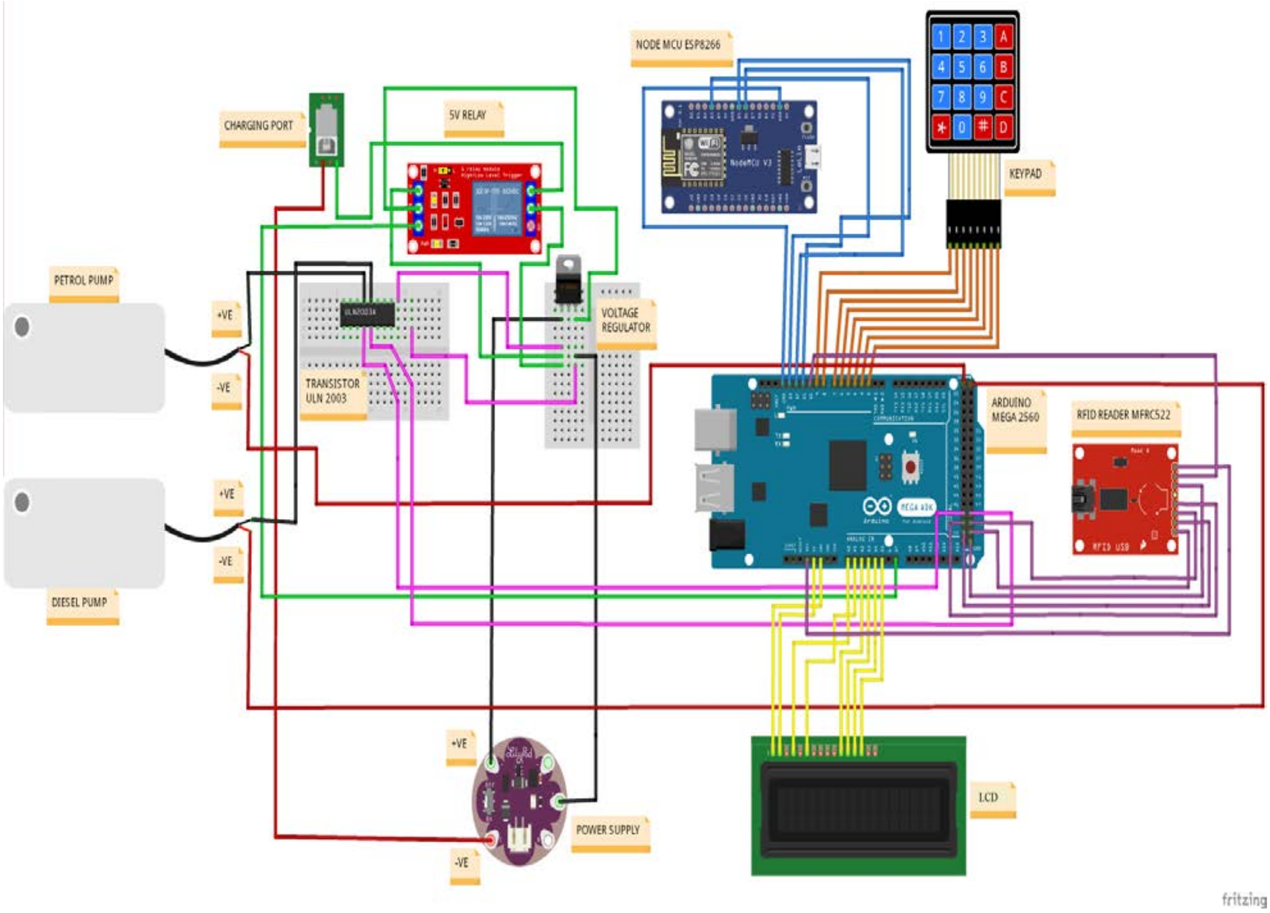


Figure 3. Circuit diagram of the automated petrol station.

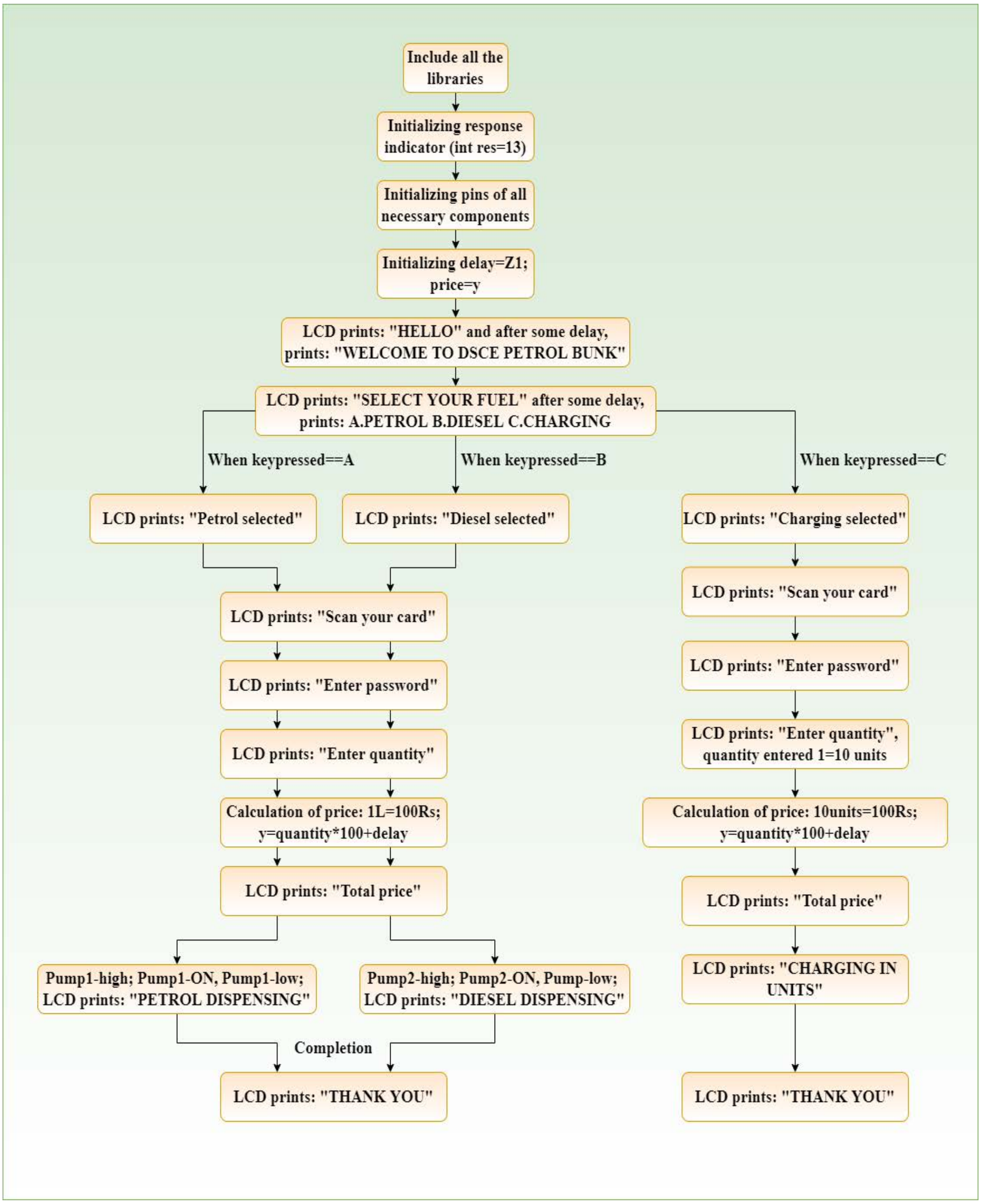


Figure 4. Flowchart for the main controller programming algorithm.

STEP 6: When the key is pressed == A, LCD prints “Petrol selected”, LCD prints “Scan your card”, then RFID operation begins.

STEP 7: Then LCD prints “Enter password” after entering; LCD prints “Enter quantity”.

STEP 8: Accordingly: the price gets calculated: 1 L = 100 rupees: y = quantity × 100 + delay; LCD prints: total price using the given formula.

STEP 9: The petrol gets dispensed by [pump1-high, pump1-ON, pump1-LOW]; finally, LCD prints “THANK YOU”.

STEP 10: When key pressed == B:LCD prints “Diesel selected”, then LCD prints “Scan your card”, then RFID operation begins.

STEP 11: Next, go to STEP 7 and STEP 8.

STEP 12: Then diesel gets dispensed by [pump2-high, pump2-ON, pump2-Low]; finally, LCD prints "THANK YOU".

STEP 13: When the key is pressed == C, LCD prints "Charging selected", then LCD prints, "Scan your card", then RFID operation begins.

STEP14: Follow STEP 7 where: (Quantity entered = 1 = 10 units).

STEP 15: Then the price gets calculated; 10 units = 100 rupees; y = quantity × 10 + delay; LCD prints the total price using the given formula.

STEP 16: Then, the charging process takes place.

3.2 Software implementation

Software programming is vital to automate, collect, manage, calculate, and analyze the processing of data and information precisely. Thus, Industry 4.0 is fundamentally a software solution. The main benefit of programming is directly related to computerization. It helps curtail the struggle with developing clean code.

3.2.1 NodeMCU implementation

NodeMCU is an open-source hardware platform based on ESP8266, which can link objects and let data transfer using the Wi-Fi protocol. NodeMCU has a more authoritative processor, larger memory, supports larger sketches, and can interact with more complex external devices. There are two available versions of NodeMCU, versions 0.9 & 1.0, where version 0.9 contains ESP-12, and version 1.0 contains ESP-12E, where "E" stands for "Enhanced". In this proposed work, the ESP-12E module has been used. Library usage helps in data transfer, configuration and data, and documentation. Initially, some variables are defined to access the data later. Wi-Fi module is mainly used to enable the internet connection to various embedded systems applications. A specific Wi-Fi module needs to connect internet by using a particular ID and password. The server provides more reliability and stability in hosting the applications. NodeMCU response pin is initialized as a "res" pin that helps transfer the data. When Wi-Fi connects, it displays the IP address in the serial monitor. When a user scans the RFID card, the card number and amount of fuel dispensing can be seen in the Arduino IDE serial monitor, and also this request is sent to the server as a "GET" request; this request is mainly used when we want to retrieve data and not make any changes to any other data on the server. If the request is valid, the fuel dispensing process is continued. Otherwise, an error message gets displayed. The programming steps are listed as follows.

STEP 1: Include all the required libraries.

STEP 2: Initialize variables like para (to access the link along with the card number), data (to access the quantity), and URL (to get the response).

STEP 3: Declaration of Wi-Fi address [i.e., Wi-Fi ID, Wi-Fi password].

STEP 4: Declaration of host address.

STEP 5: Initialize res = D3 [NodeMCU response variable].

STEP 6: Once the Wi-Fi is connected, it serially prints "Wi-Fi connected" with "IP address".

STEP 7: Declaration of a para variable.

STEP 8: The details are stored in the app server when a user scans the card and enters the quantity.

STEP 9: The URL is generated by the addition of para and data variables, i.e., URL = para + @ + data.

STEP 10: The fuel gets dispersed if the response is valid.

3.2.2 Android application

The American technology company Android Inc. started working on Android in 2003 as a project to create an operating system for digital cameras. The project was transformed in 2004 to become a mobile operating system. Google Inc., an American search engine business, acquired Android Inc. in 2005. The Google team chose the Linux operating system for personal computers as the foundation for the Android project.

According to a Google announcement, the Open Handset Alliance was established on November 5, 2007. It groups numerous technology and mobile phone companies, including Intel Corporation, Motorola, Inc., NVIDIA Corporation, Texas Instruments Incorporated, LG Electronics, Inc., Samsung Electronics, Sprint Nextel Corporation, and T-Mobile (Deutsche Telekom). The group was established to advance and publish. Android is a free, open-source system with third-party application support. Android-based smartphones use wireless networks to access capabilities like one-touch Google searches, Google Docs (word processors, spreadsheets), and Google Earth (satellite mapping software).

A software program that runs on the Android platform is known as an Android app. The acronym APK, which stands for Android package, is often used to refer to a file. The app code, resources, and metadata are all contained in this file, which is a Zip archive. The virtual machine runs Android apps, which can be created in Java, Kotlin, or C++. Android Studio is the authorized development environment. The Android Software Development Kit (SDK) can be downloaded from the Android website to create apps. The SDK comes with numerous tools, code, and all the libraries required for Android.

XML for Android app development: Xtensible Markup Language is called XML. For describing data, XML is a markup language similar to HTML. The tags in XML are not fixed in advance. To create the tags in XML, we must devise a method. XML tags are utilized to store, organize and describe data contents. Both scalability and development are straightforward. The XML markup language, which is purely decorative and doesn't create the layout, is used in Android to implement User Interface (UI)-related data. In XML, just tags exist; to use them, you only need to call them. The UI for an Android App is constructed to grade main layouts and widgets. The layouts are View Group objects or vessels controlling how the child's view should be on the screen. Currently, widgets are view objects like text boxes and buttons.

App resources: Resources are the additional files and stationary content that the code uses, such as bitmaps, layout definitions, user interface strings, and animation instructions, where **Table 1** describes the resource directories maintained inside the Android project.

Java for Android app development: The main objective behind Android development was to create a platform-independent application environment that could run on each device. As we know, Java previously had this quality, so Java was chosen for android development. Android applications run on a superior virtual machine called the Java Virtual Machine (JVM). Android applications can run on any device where a special JVM is implemented. This way, Android applications are compiled and run in an optimum performance environment with the feature of platform independence.

Table 1. Resource directories are maintained inside the Android project

Directory	Resource type
Animation	Property animations are described in XML files
Drawable	To use the images, bitmap files (.png, .jpg, and .gif) or XML files may be compiled
Font	Font files with postponements such as .ttf, .otf, or .ttc, or XML files that include a < font-family > element
Layout	XML files that describe the design of a user interface
Menu	XML files express app menus, such as an Options Menu, Context Menu, or Sub menu
Mipmap	Drawable files for dissimilar launcher icon densities
Navigation	XML file that uses UI panel and expressions the app's main navigation menu
Raw	Random files are to be saved in their unprocessed state
Values	XML files cover simple values, such as strings, dimensions, and colours

The primary advantage of using Java for Android development is that it provides object-oriented programming concepts and is more capable because they are extensible, scalable, and adaptable. It includes a comprehensive library of standard design patterns and other best practices because it is open-source and more plexiform for expanding mobile apps. This permits you to make modular projects and recyclable code. Java app development also comes with a collection of outstanding programming tools, making it much calmer to work on and construct an application that perfectly suits the needs. Java has an extensive set of libraries. Making use of these libraries is simple. Android

SDK has many typical Java libraries included. These deliver functionalities for data structure, math functions, graphics implantation, networking functions, and much more. These Java libraries enable us to perform all other tasks. This way, java assistances develop Android applications fast and inefficient manner. When it comes to the design of a mobile app, security is its essential aspect. Keeping security in mind, Java is the first choice of android app developers because of its ease of use, robustness, security features, and cross-platform development competencies. Security is an essential part of any mobile app design. The Java programming language was created with security, including the compiler, interpreter, and runtime environment. Robust means stability and reliability. Java puts much focus on testing for possible early errors, as Java compilers can identify several issues that could occur during the time in other languages. Due to its heftiness, ease of use, cross-platform capabilities, and safety features, Java app development has become the first choice for establishing Internet solutions worldwide.

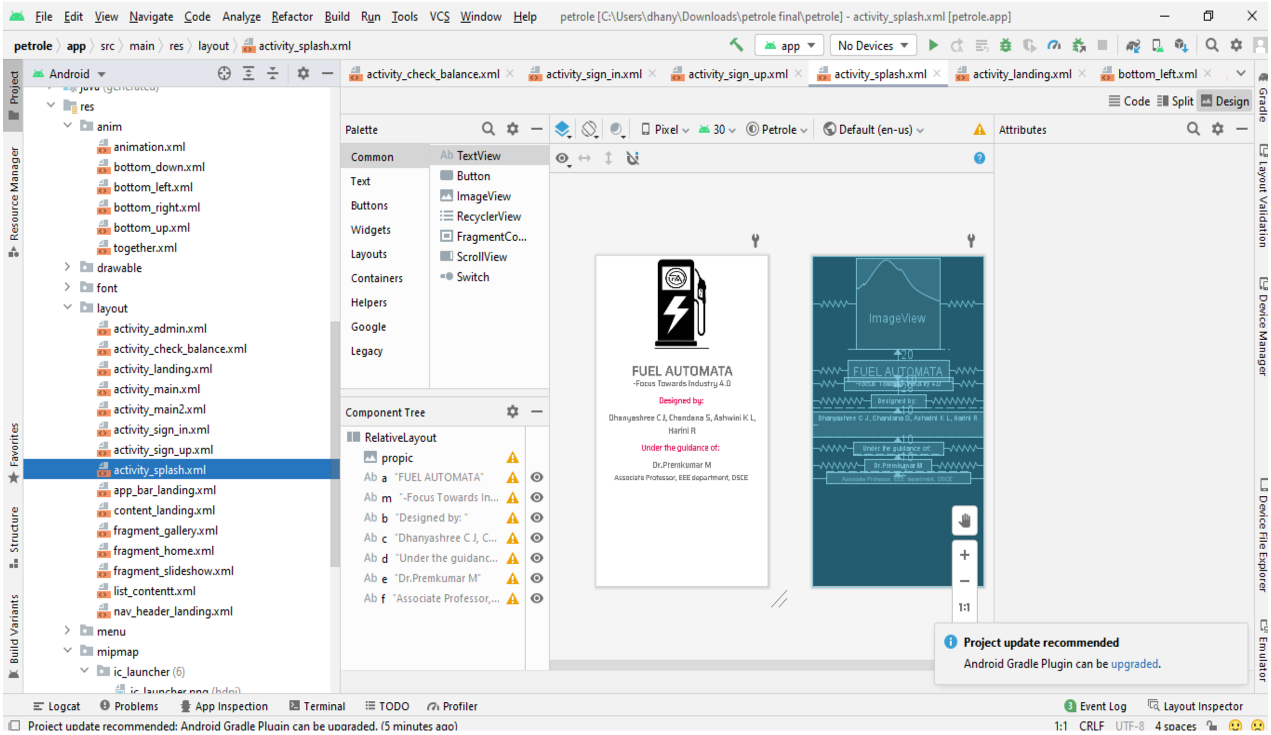
Database for Android development: A database is a collection of interrelated data that helps in the well-organized retrieval, insertion, and deletion of data from a database and organizes the data in tables, views, schemas, reports, etc. For instance, a school database organizes information about students, instructors, administrative staff, etc., making it easier to insert, retrieve, and delete data. Data definition language deals with database schemas and metaphors for how data should be stored in databases.

Android-SQLite database: Structured Query Language (SQL) is a standard language for storing, manipulating, and retrieving database data. Data is kept in a text file on a device using the open-source SQL database SQLite. The SQLite database implementation is already incorporated into Android. The SQLite database implementation is already incorporated into the Android software. SQLite supports all the relational database features. To access this database, there is no need to establish connections like JDBC and ODBC. It can do operations on data such as adding new data, updating, reading and deleting this data. The Android handles database creation and version control. To perform any database operation, you must implement the on Create() and on Upgrade() methods of SQLite Open Helper class.

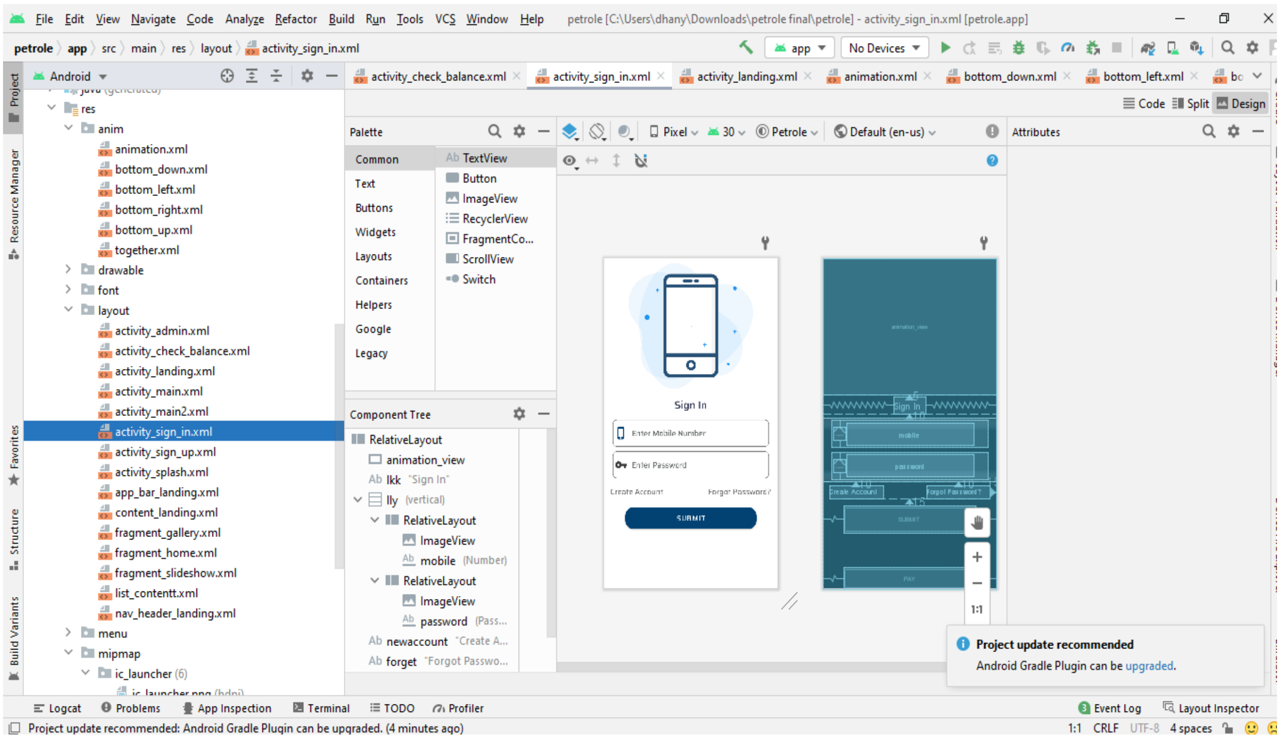
3.2.3 Design of the Android app

The back end of the app is developed in Java, UI is developed in XML using Android studio. The design of the android app includes developing the code for XML files and adding the images to the UI using a drawable folder to make an attractive impression on the user. It mainly uses a relative layout to make the user interface. The design of the first page in **Figure 5(a)** is building the layout of the project details page, which is used to view the project title and logo. In this study, the main layout is the relative layout for the arrangement of the position of elements for the user interface. The following statement to define it in this way Android: layout align Parent Top = “true”, Android: layout align Parent Left = “true”, and Android: layout below = “@ + id/element name” is defined for bringing the elements in line one below the another, with specific width and height attributes. If the above code is written, the part is aligned on the top left. The view design option is selected from the top right corner of the layout editor to design the overview of the sign-in page. By selecting the suitable XML activity file and developing the code, we can build the layout of the users’ sign-in page for the second page in **Figure 5(b)**. The palette option on the left side of the editor window contains various views and view groups that can be dragged into the layout; the text view is selected for adding text. The component tree appears on one left below, which displays the hierarchy of the components in the present layout; the animated view of the picture is designed, and the space for mobile numbers and enter passwords are given.

In **Figure 5(c)**, the suitable activity XML code file is chosen, and the account page of the new user page is created. The text view is chosen in the dialogue box, and the relative layout

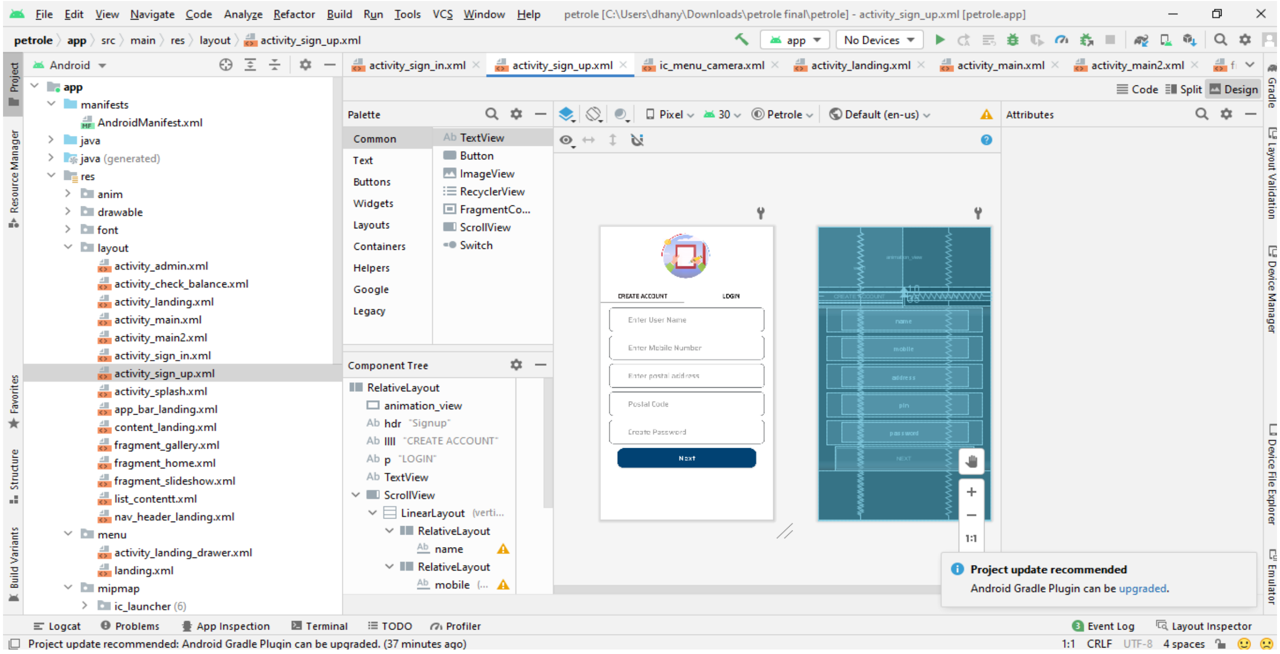


(a)

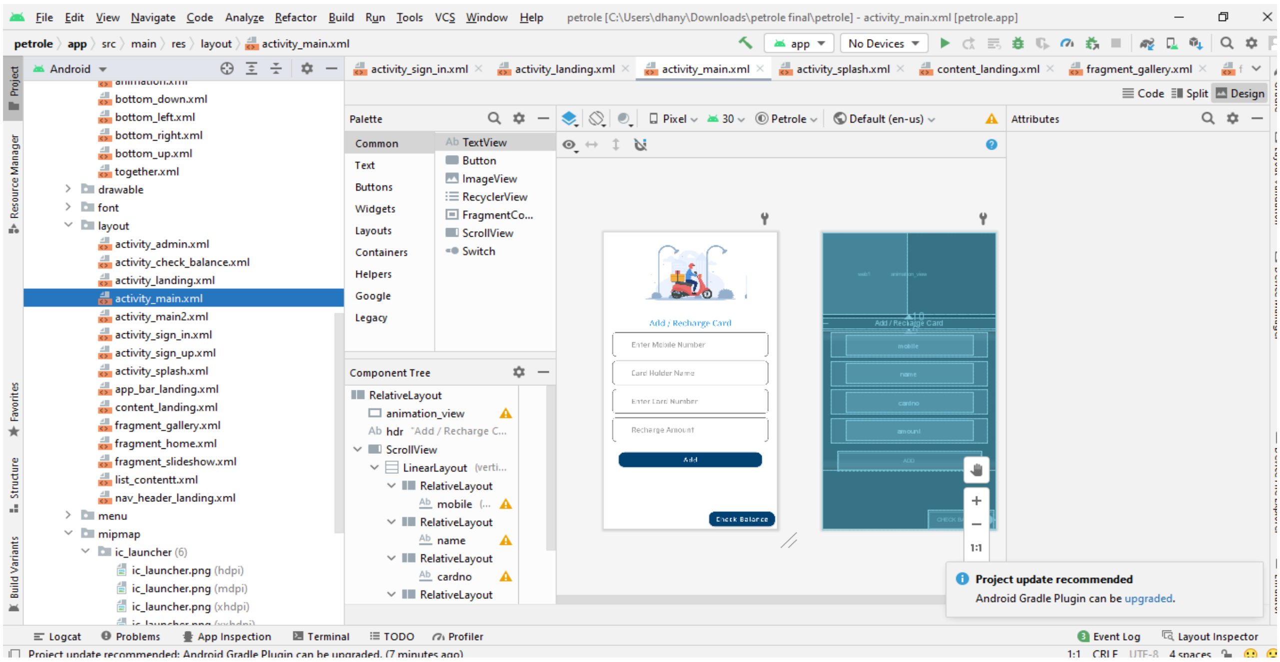


(b)

Figure 5. (*Continued*).



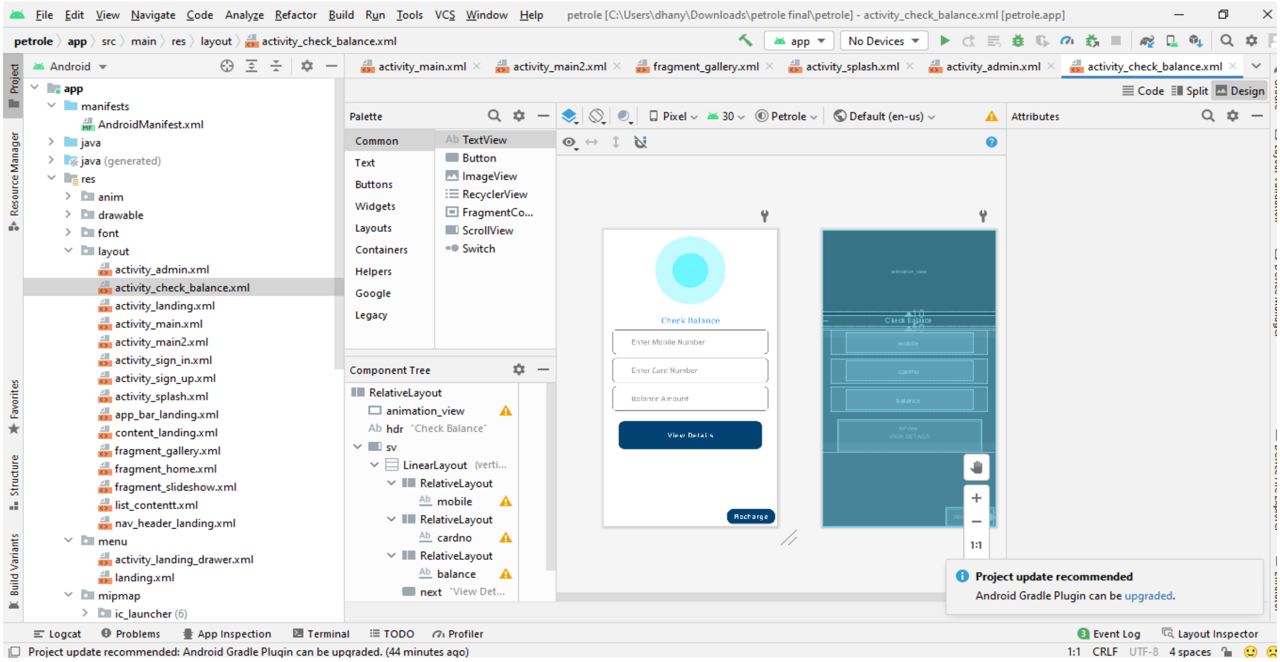
(c)



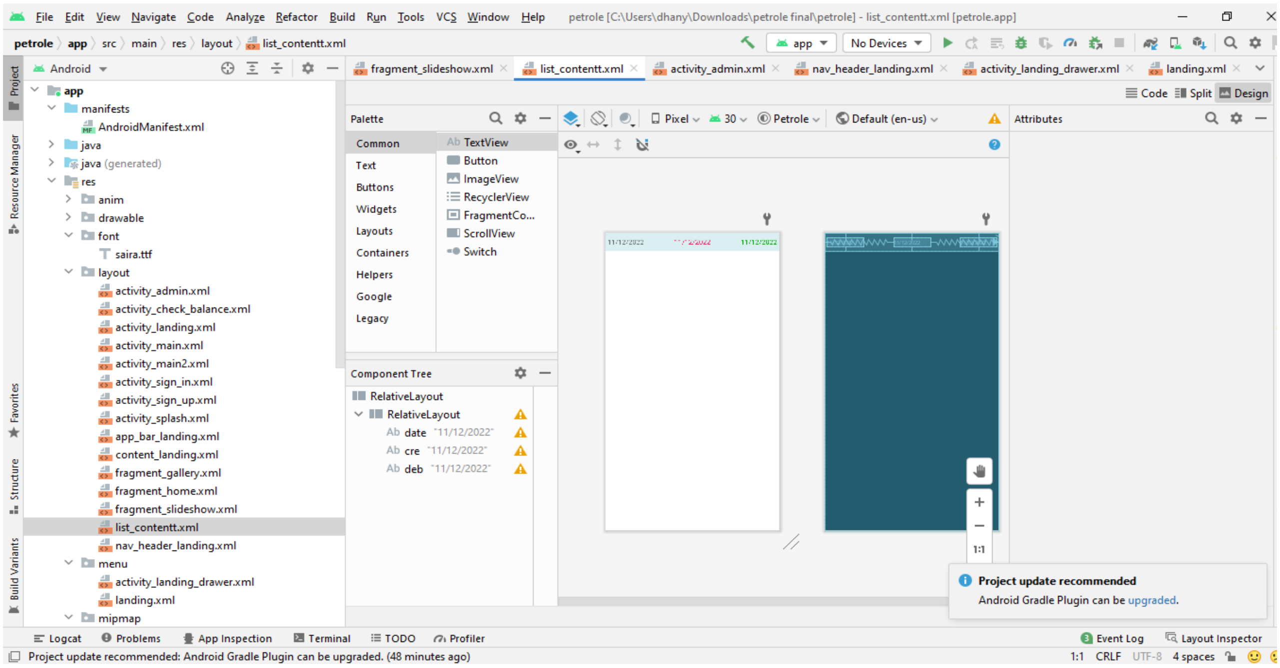
(d)

Figure 5. (*Continued*).

of the elements of login username, postal code, postal address, and password detail box is provided for the page content design. These design functions are linked using the sign-in page in **Figure 5(b)**. In **Figure 5(d)**, the preview of the new card recharging page is built by choosing an activity in the XML file, and of the relative layout editor, the elements are provided in scroll view of mobile number, card number, cardholder name and the recharge amount for text filling spaces and the animated view of the picture at the top is added. In **Figure 5(e)**, the check balance page layout is designed in the activity XML, check balance file and the image is added with a Relative layout animated view. The mobile number, card number, and check balance box elements are given, and the next button is positioned towards the bottom of the page layout. In **Figure 5(f)**, the sample details of data and time are provided for the list to create the transaction history page on the user side. **Figure 5(g)** similarly pro-



(e)



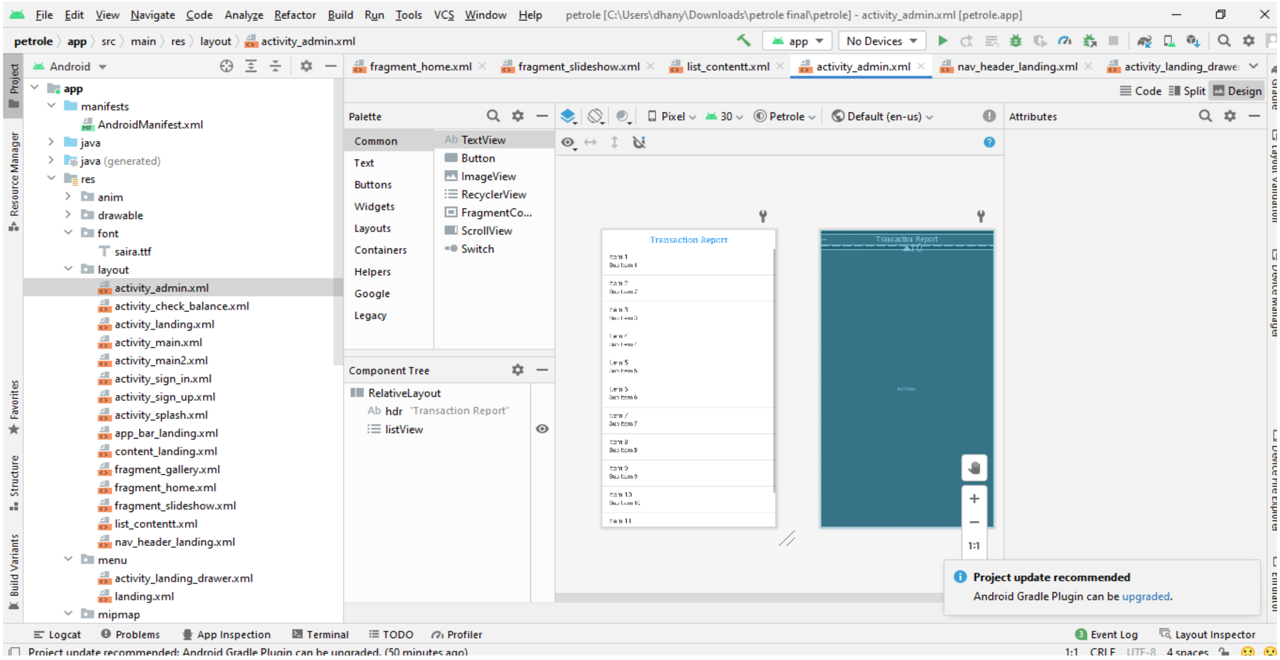
(f)

Figure 5. (*Continued*).

vides the sample data to add as a text view, and the code file is run to create the interface's final transaction history page of the service provider. To see all known issues in a window below the editor, click show warnings and errors on the toolbar here in the components tree dialogue box in the window. Hence, after calling these XML functions in the main activity Java file, the app is compiled, and the .apk file is built to test and verify the application.

3.2.4 Working of the Android app

Android application working on the user's side: The main purpose of developing this Android app is to get access to the RFID card to use the fuel station. The above flowchart explains the working of an android app for users. Initially, the user



(g)

Figure 5. Design layout of the Android app: **(a)** Design of the project details page, **(b)** Design of the sign-in page, **(c)** Design or create an account page for the new user, **(d)** New card adding/recharge page, **(e)** Design of check balance page, **(f)** Design of transaction history page for the user, **(g)** Design of transaction report page for the service provider.

needs to create an account by clicking on the create account option and then register by providing details like user name, mobile number, postal address, postal code, and password. Then the account is registered. After that, the user must sign in using the same mobile number and password to log in successfully. The next step includes adding the RFID card details. To add the card, the user must provide the same mobile number, cardholder name, and particular card number. If all the details are valid, then the card is added successfully. The user can also recharge the card on the same page by entering the recharge amount. At the bottom, there is an option called "check balance".

It is used to check the balance amount on a particular card. By clicking on the check balance option, the user must provide their mobile number, and then all other details, like the card number and the balance amount, are displaced. Once the user enters the fuelling station to fill the tank, then in the fuel LCD, the amount is calculated based on the quantity the user enters, so the displayed fuelling amount gets debited from the user's card. An error message is displayed on the LCD if the balance is not present on the card. The user then has to recharge the card in the application. **Figure 6** explains the working of the Android application on the user side. **Figure 8** describes the working of the Android application on the service provider side. The user can verify all the debit and credit details on the check balance page by clicking on the view details option to make all the transaction details visible to the user. Once the fuelling and transaction process is over, users can get a logout from the app.

The Android application works on the service provider side: Here, users and service providers can use the same application. The above flowchart illustrates the working of the Android app for the service provider. The service provider must log in using credentials like mobile numbers and passwords. From the particular details, if the service provider logs in, all users' overall transaction reports, including debit and credit history, would be displayed as a transaction report with usage date and time. **Figure 7** illustrates the flowchart of the Android application of the service provider.

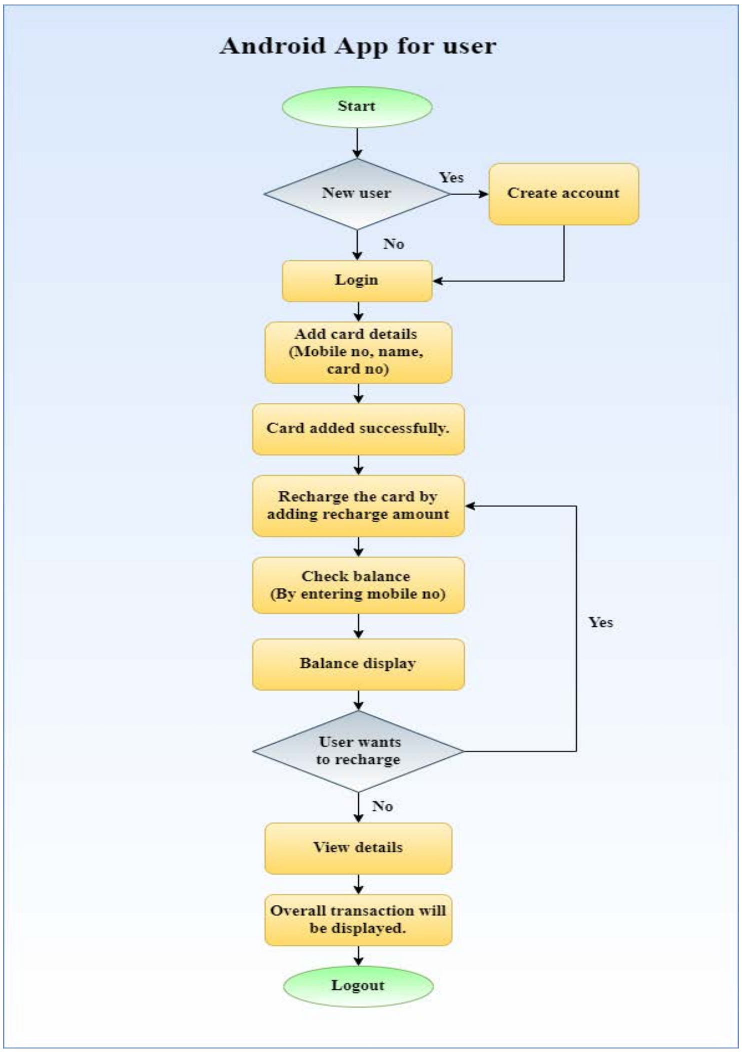


Figure 6. Flowchart of the Android application working on the user's side.

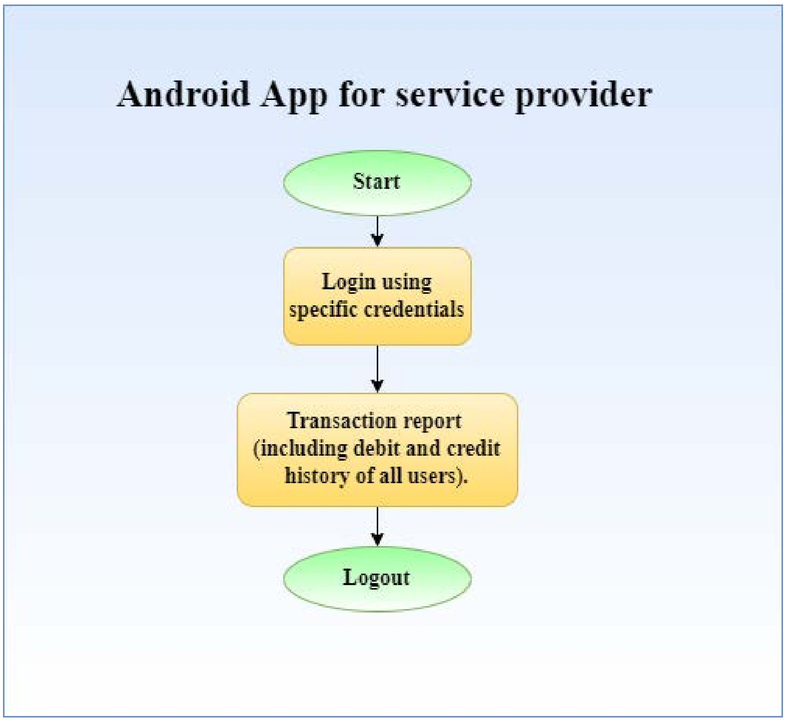
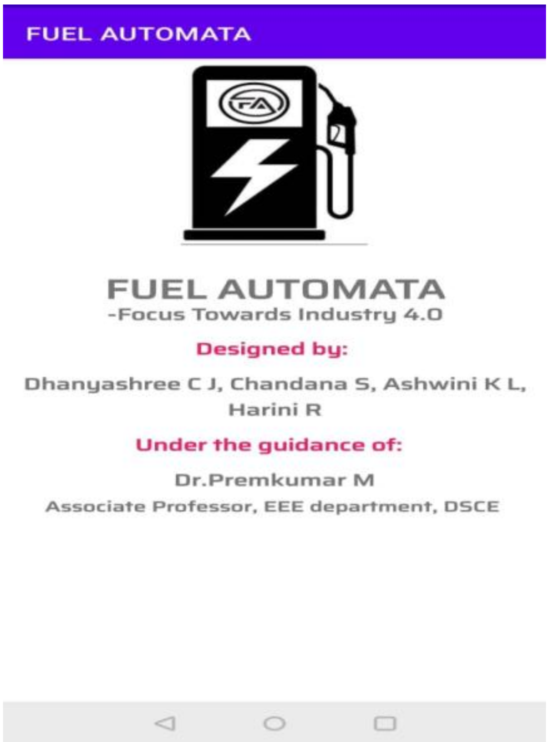


Figure 7. Flowchart of the Android application working on the service provider side.

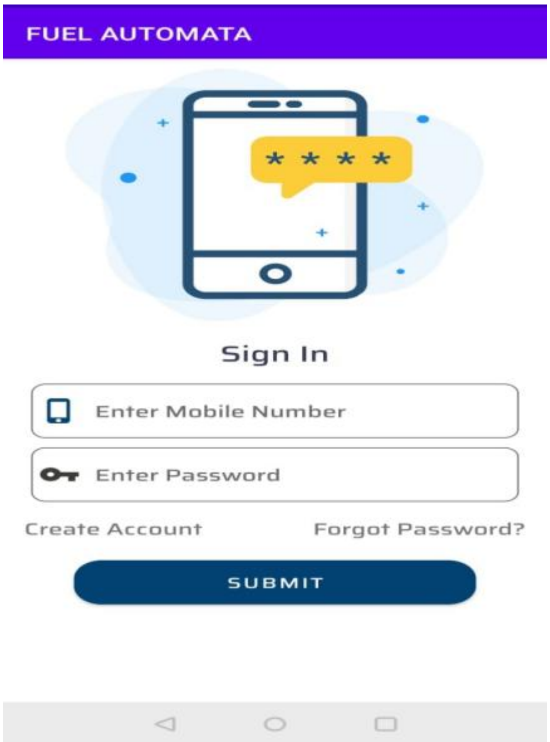
3.2.5 Demonstration of Android application-fuel automata

An Android application has been developed using an Android studio named as "Fuel Automata". As described in the flowchart and **Figure 8(a)**, when an app is opened, it displays "Fuel Automata - Focus towards industry 4.0". After the delay, as in **Figure 8(b)**, a sign-in page appears; if the user is new, they must create an account by clicking on create an account. The new user must create the account by entering the name, mobile number, postal address, and postal code and creating a password, as in **Figure 8(c)**. After creating the account, the user has to sign in using his mobile number and a password given while creating an account, as in **Figure 8(b)**. The user can also check his card balance by clicking on the bottom side of the page to check balance, as in **Figure 8(d)**; once the user enters the mobile number on the check balance page then, automatically, the card number and the remaining balance is displayed as in **Figure 8(e)**. The user can also view recharge and transaction history by clicking on view details which shows the date and time when the fuel has been dispensed, and the card has been recharged from the date the user got access to his card to till date, as in **Figure 8(f)**. Once the user has logged in to the account if the user is new, then has to add the card and then recharge it by entering his mobile number and cardholder name; enter the card number, and then the user can recharge the card as in **Figure 8(d)**. If the card is already added, once the user enters his mobile number, the cardholder's name and the card number are displayed, and then the user can recharge the card.

The same app can also be used by the service provider, as shown in **Figure 7**, where a service provider can log in with certain specified credentials and the password given to the service provider, as in **Figure 8(g)**. The service provider gets the users' transaction history through this app, as in **Figure 8(h)**.

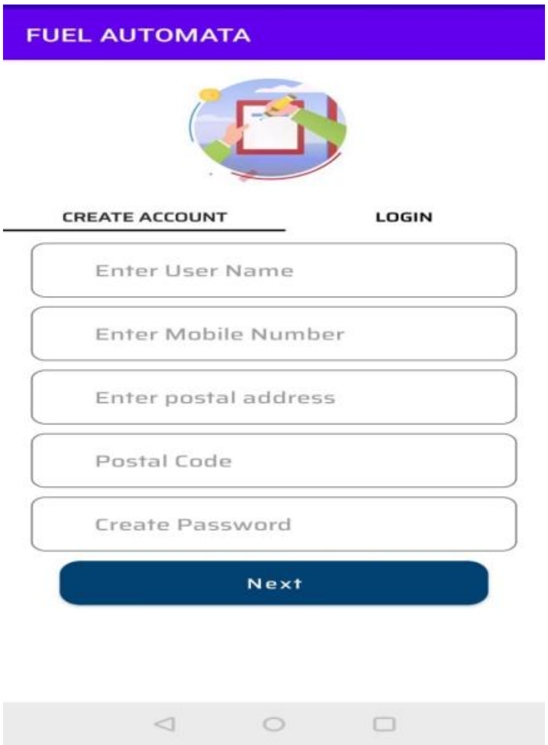


(a)

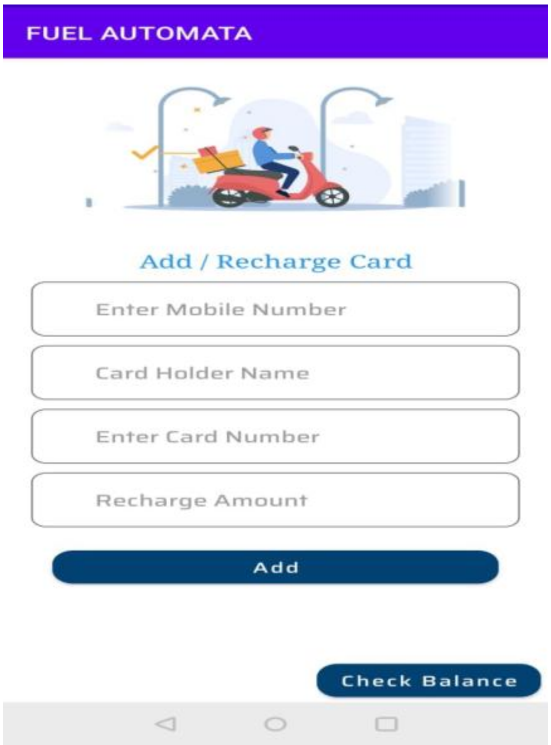


(b)

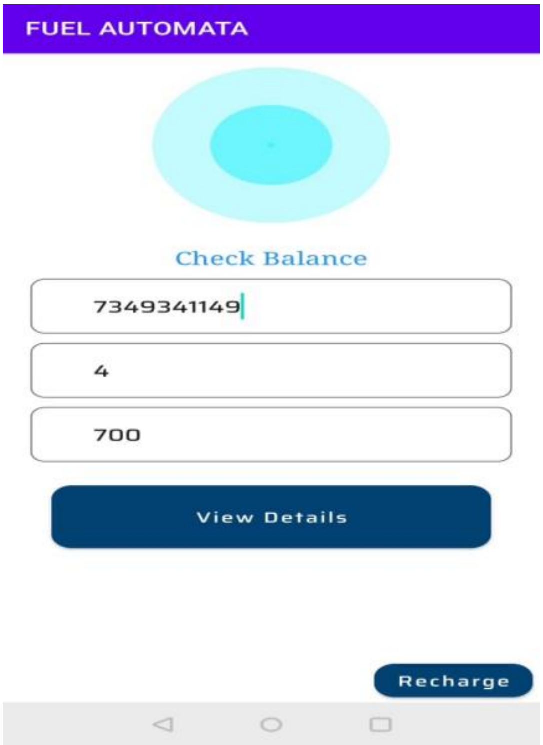
Figure 8. (*Continued*).



(c)



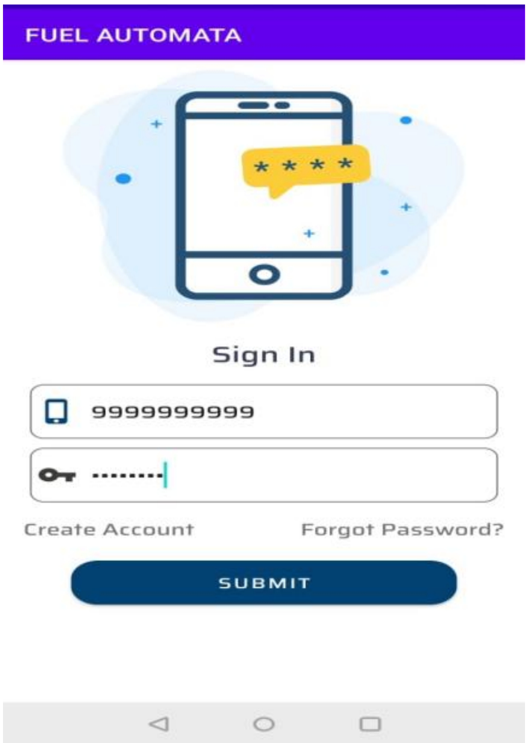
(d)



(e)

(f)

Figure 8. (*Continued*).



(g)

(h)

Figure 8. Fuel Automata app. **(a)** Project details page, **(b)** Sign-in page, **(c)** New account create, **(d)** Add/recharge card, **(e)** Check balance login, **(f)** Check balance details, **(g)** Login details for service provider, **(h)** Transaction report for a service provider.

4. Results and discussions

The automation process in the fuel station provides the advantages of improving overall productivity and quality, adding flexibility, and increasing safety while reducing errors and waste. But by using a current-day petrol station, the overall time consumed by each user is around 7–8 min, indirectly affecting all the customers waiting in the queue. Using unmanned, i.e., an automated fuel station, decreases the time consumption to around 3–4 min because it doesn't require any cash exchange/online payment. There is a similar example in a Metro station while entering and exiting. With the help of RFID technology, an RFID card is used as a debit card to make payments, undergo self-serviced transactions, and access user details. The quality of fuel dispensing is also an important aspect for all users.

With the help of automation, the fuel quality can be retained and indirectly avoid the robbery and adulteration of the fuel. In normal fuel stations due to, adulteration leads to dangerous accidents. Currently, fuel station inaccuracy in fuel dispensing leads to the dropping of the fuel, which may lead to fire catching. To overcome the issue, an automated fuel dispensing system accurately calculates and stops the dispensing pump and avoids dangerous incidents. Using a single product, diesel and petrol can be dispensed with the help of two different pumps, making the initial installation process easier. The important aspect is maintaining all the user data on a server; this helps for future reference. Retaining the data in the same application for both the user and service provider is a unique option. The installed package is handy so customers can feel comfortable with the designed product.

The self-automation system developed is highly efficient as it updates within a fraction of a second; all the user activity details are updated in the backend app system for full access to the user and service provider side. There is the sequential implementation of the hardware interfacing with the RFID technology without any interruption, and the desired output is obtained by this system implemented. The interfacing between hardware and software is well implemented in our proposed technology, where the service provider gets time-to-time updates of the user without any delay for customer usage. The presented strategy shows that the entire module idea built is useful in effectively monitoring and acquiring complete fuel dispensing data. The system also reflects the power of using RFID as the only identification technology presented in this application, without the need to further technologies that require further equipment to be installed, which can raise the implementation cost. The proposed system facility can check the quality of the fuel. These observations are real-time.

The system provides a reliable fuel distribution system along with the parity check. This helps reduce human error during distribution, fuel embezzlement, and adulteration activities at petrol pumps. Such malicious activities can lead to the cancellation of the petrol pump license. This is not only beneficial for the petrol pump owner, but also the company's service. Hence the accuracy of the fuel dispensing of the proposed system worked here is highly efficient. The proposal includes a full-fledged product of automated RFID technology with app-enabled payment provided with a backend database system that is used effectively to collect, store and access the necessary information of users. Also, it avoids privacy and security issues, which have been enhanced using scalable serverless authentication and search protocols for the RFID reader and tag communication for pervasive environments. Our proposed project designed and developed a customized infrastructure based on smart devices of RFID technology to enforce the privacy of individuals. RFID tags have more qualities like non-contact, reading speed, no wear, long life, customer-friendly, and safety purpose than the traditional information collection method. Hence this RFID technology implemented has distorted the conventional approach of information gathering and made ways for better customer approach usage in the present fuel systems scenario. This system is highly efficient, around 98%.

The petrol pump business has always been considered one of the leading profit-making businesses, not just in India but globally, largely due to growing demands for transportation. In India, starting a petrol pump is a high-investment business idea. Still, it is also a very profitable one. The minimal cost of investment and funds varies with location and costs around ₹15 Lakhs for rural areas and ₹25 Lakhs for urban areas and ranges up to ₹2 Crores depending on the busy areas and location for the purchasing cost and funds required. With petrol pump owners making around ₹3.5 lakhs monthly profit if they can sell 400,000 L of petrol at a commission rate of 3.0 L. The owner should have the funds to purchase or rent the requisite land and invest in the gas station construction. It is beneficial if there is a water and electrical connection in the ground. A new fuel pump franchise's overall success and profitability are determined by the location and distance between this petrol station and the others in the area. The size of the gas/fuel station, maintaining top conduction of the petrol pump, adequate advertisement of other features such as offering discounts. The proposed study is a smart, automated solution for existing petrol pump systems that pave the way for user-friendly, easy access. The product aims to be implemented in real-time petrol stations, a highly efficient portable system. It is designed as an alternative for high reliability with low-cost, high efficiency, and power consumption and a solution to the above problems. If one has to start a smart, automated petrol system, the investment is largely reduced, and the owner is highly benefitted as the cost of investments of the components for purchasing is low.

The overall cost of development of RFID technology dispensing system for all the purchase of hardware implementation costs around ₹10,000, and its further implementation in real-time could be an approximation cost of ₹1 Lakh below ₹10 Lakhs which is highly profitable for the investors and the owners when compared to the manual petrol stations. The cost of purchasing land areas with a low budget and advertising is eliminated in our proposed plan. This franchise can be implemented at all stations and branches as an auto-guided mechanism with low investment cost and high profitability as time and power are saved. Employment and salaries of staff and labourers can be minimized, and the queue of customers can be reduced, making it easy for business management. **Table 2** gives the overall cost estimation of the proposed study.

Table 2. Cost estimation of the proposed study

S. No	Component	Cost (₹)
1	App hosting server	4,000
2	Arduino Mega 2560 with cable	1,750
3	RFID reader with cards	270
4	NodeMCU ESP8266	266
5	NodeMCU cable	169
6	4 × 4 Keypad	150
7	16 × 2 LCD	150
8	Voltage regulator, LM7805 with filters	100
9	Power adapter	100
10	Hardware setup box	100
11	Pumps for dispense	88
12	Jumper cables	54
13	1-channel 5V DC relay	50
14	Mini syntax (2)	40
15	PVC transparent pipe	40
16	Conduit casing pipe	40
17	Relay driver IC ULN2003	38
Estimated cost (₹)		7,405

Given the importance of the growth of industries, this automated technology makes the process more comfortable for the dealers and the customers; the goal of the proposed framework proved a cost-efficient real-time implementation with a low-budget plan and highly efficient service accuracy for the customers. According to the circuit diagram, the overall hardware setup is done. The whole idea of the study is to design and develop a full-fledged product, so this designed product is ready and can be implemented in fuel dispensing stations across the country. **Figure 9** illustrates the experimental setup of the proposed study.

Figure 9. Experimental setup of the automated petrol station.

The experimentation has been carried out as mentioned in **Figure 1**. The RFID works according to the Arduino programming algorithm, as explained in **Figure 4**, for the complete integration of software and hardware so that the operations are done in the hardware part and get updated in the designed app. **Figure 10** shows the RFID processing.

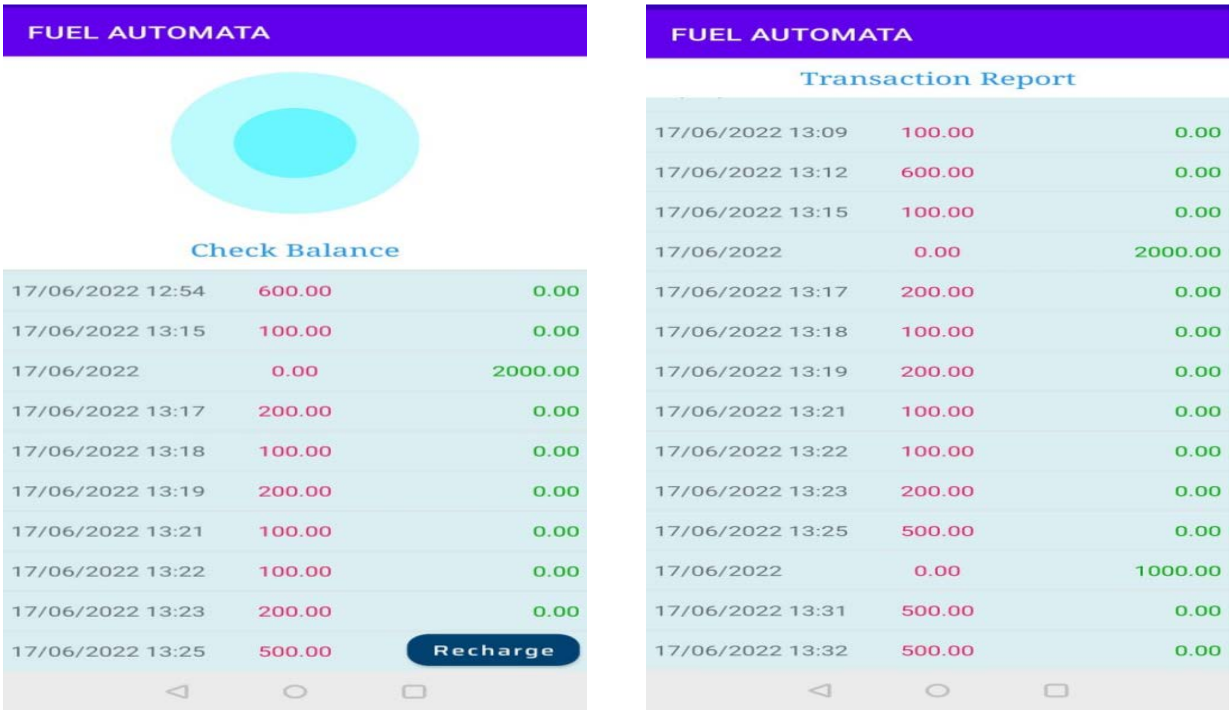
Figure 10. RFID processing steps.

Transaction history shown in **Figure 11(a)** is mainly required for the user to verify all the transactions, including debit and credit activity. Updating every activity detail helps the user to check and use the petrol station by verifying his RFID balance amount. This makes the process easier and more comfortable.

According to **Figure 11(b)**, the service provider is responsible for maintaining the details of all the users. This helps in retaining the details for future reference. So, at the end of the day service provider can verify the transaction report and overall profit daily.

4.1 Discussions

The proposed study presents a fuel dispensing system based on RFID technology. RFID-based automated fuel dispensing system mainly reduces human work, develops an auto-guided mechanism, and implements the task sequentially using RFID technology. These systems are less time-consuming and extremely reliable. The RFID reader, which is present here, has a radio transponder that acts as an antenna and ranges from 125 kHz to 2.4 GHz, and it uses electromagnetic fields to identify the signals corresponding to the RFID tag. The system can improve fuelling to make it much easier, more secure, and more reliable. It prevents unauthorized fuelling by assigning a specified amount of fuel for registered vehicles, depending on their types, within a specific period so that each vehicle gets a sufficient amount of fuel. It also provides efficient statistics about the various quantities of fuel at the stations. The implementation of RFID technology has changed the operation of conventional fuel dispensers. The hardware and software that base the Arduino platform are to minimize complexity when working on an electronic project.



(a) (b)

Figure 11. App results. **(a)** check balance details for the user and **(b)** transaction report for the service provider.

This paper has implemented RFID as a cashless payment system for the fuel station. This idea is basically IoT-based. The IoT concept is quite prevalent in the fuel industry, with its automation techniques and rendering simplified solutions for management.

Moreover, it offers judicious fuel use, thereby eliminating the possibility of fuel wastage. The IoT in this proposed project describes physical objects (or groups of such objects) embedded with hardware components, processing ability, software, and other technologies that connect and exchange data with other devices and systems over the Internet or other communication networks. The IoT architecture was used in developing a smart transaction system by developing an Android app for app-enabled payment with the app database access system to collect and maintain app user details effectively. The hardware and software that base the Arduino platform are to minimize complexity when working on an electronic project. The official IDE for creating Android applications is called Android Studio. After downloading the Android SDK file, the components used for creating the applications are Android Studio, Android SDK, and Android virtual machine. This software is open access based, which was used for programming the app interface and a database management system equipped to show the transaction details of the user and service provider. SQL Server is a database management system that Microsoft develops. This is built for the basic function of storing and retrieving data as required by applications, and here, it is made used for updating the transaction credential details for the database storage system. The app database is developed to collect, store, update and maintain all the user security details.

The NodeMCU is a low-cost open-source IoT platform with a more powerful processor and larger memory, supports larger sketches and can interact with more complex external devices. The internet connection was enabled through the Wi-Fi connectivity of NodeMCU based on ESP8266, which can connect objects and let data transfer using the Wi-Fi protocol. This application was easy to access platform, including all libraries for Arduino IDE. It provided a good internet connection for a wide range suitable for the hardware implementation used with larger memory, and extensive complex devices can be connected through this Wi-Fi technology in the proposed design hardware. Arduino plays a key role in hardware, and NodeMCU helps transfer the response to the Arduino. Thus, effective interface between the hardware components and the software was obtained and implemented using these technologies for our project idea. By controlling and observing microcontrollers, utilizing modern technology, such as cell phones, to control numerous devices dependent on IoT, and building on the RFID framework proposed, the proposed study thus plans to audit current methodologies for planning excellent petroleum pump frameworks with low costs.

5. Challenges and drawbacks

5.1 Challenges

This concept is intended for a security system only respected authorities can access. The initial difficulty we encountered was integrating the hardware parts with the software backend app system created in conjunction with the database. The Arduino Mega 2560 was preferred over Arduino Uno as it has more flash memory and space to read the data and is more efficient when compared to Arduino Uno in processing and implementing the system hardware designed in the proposed study. The selected Arduino Mega 2560 can read data from the RFID reader, perform a task according to client specifications, and withdraw the appropriate amount from the user's card. To enhance the current gasoline dispensing system, RFID and Arduino are utilized. Minimizing human labour enables an auto-guided mechanism to complete the duties in sequence. Thus, these systems are very time-efficient and very dependable. IoT applications are rising today, and connecting objects is becoming more important. There are various ways to connect different objects, such as Wi-Fi protocol. NodeMCU is a low-cost open-source platform based on ESP8266, which can connect objects and let data transfer using the Wi-Fi protocol. This application was an easy-to-access platform, included all libraries for Arduino IDE, and provided a good internet connection for a wide range suitable for the hardware implementation used with larger memory and extensive devices that can be connected. The ESP8266 NodeMCU chip requires a 3.3 V voltage power supply. It should not be battery-powered with 5 V like other Arduino boards and NodeMCU. The comparison is based on the RFID technology's most important required features for IoT projects. For charging the quantity of the fuel in litres of the motor pump in the system initially, a 3–6 V mini pump was used and a 5 V channel relay; hence we couldn't achieve the maximum rise of charging level at the initial steps, and later we obtained the required charging amount after providing the suitable value by raising the count of input. The proposed study is equipped and displays the transaction history of the customer usage details for petrol and diesel together in the backend database management as it was an app-enabled recharging system.

5.2 Drawbacks

Nowadays, there are no accurate records of the various quantities of fuel being dispensed at the existing fuel stations. All such reports are usually paper-based and lack the required precision to control this valuable commodity, which could lead to fuel misuse or illegal sale. This proposed model presents a control system based on RFID technology to monitor the supply and dispense of vehicle fuel. Therefore, per day, fuel consumption happens at fuel stations can't be determined. There is a possible impact of network outages for a wide range of use and unfamiliarity with payment methods. There are chances of empty credit accounts. This proposed system design must have included warning measures to the customers about the low card balance for the efficient working of the system. It is an easy authentication service for several common tools like biometrics, software, etc., and ensures and gives solutions for trust-related difficulties in these networks. This suggested approach might be helpful given society's rising instances of adulteration. Engine longevity may be impacted by adulterated fuel, which may also result in increased pollutants. In India, where fuel costs rise daily, gas station owners use immoral tactics to boost their profits. Fuel theft or embezzlement costs the gas station company money.

The suggested system can stop these situations from happening. There is a lack of integration of the payment gateways, like Gpay, PhonePe, and Paytm, to the hardware implementation. This self-service facility is an automated pump device that also protects customers from fuelling at the gas station without any involvement of the service provider, so the risk of carrying money every time is minimized. The product thus developed is paperless technology. Because of automation, it makes it a hassle for people to adjust to the app-integrated system and time inconvenience for app installation, which is not handy for everyone. Also, due to automation technology, the employment of labour and staff working at fuel stations is significantly reduced.

Certainly, here are some points on how the contributions highlighted in the paper support the novelty of the research.

- The proposed smart fuel dispenser system using RFID technology and IoT-based monitoring represents a novel approach to fuelling operations in the automotive industry.
- The proposed system offers several advantages over traditional fuel dispensers, including increased accuracy, efficiency, safety, and environmental sustainability.
- RFID technology automatically identifies and tracks vehicles, drivers, and fuel types, ensuring accurate and reliable fuelling transactions.
- IoT-based monitoring provides real-time data on fuel levels, dispenser functionality, and vehicle movements, optimising fuelling operations for maximum efficiency.
- The proposed system's potential to revolutionize the fuelling industry by improving operations and reducing costs and environmental impact significantly contributes to the field.
- The study provides empirical evidence of the feasibility and potential benefits of the proposed system, highlighting the system's potential to transform the automotive industry.
- The proposed system's potential to be extended to other industries, such as aviation and maritime, further highlights its novelty and potential impact.
- Overall, the contributions of the paper offer a new and innovative solution to the challenges facing traditional fuelling systems, making a significant contribution to the field of automotive engineering and technology.

To strengthen the argument for the scientific novelty of the proposed smart fuel dispenser system using RFID technology and IoT-based monitoring for automotive applications, this study could highlight the following:

- Integrating RFID technology and IoT-based monitoring in fuel dispensers is a relatively new concept, with only a few existing systems in use.
- The proposed system represents a significant advancement in fuelling technology, offering automated fuelling transactions, real-time monitoring, and data analytics capabilities.
- RFID technology and IoT-based monitoring in fuelling systems can revolutionize the automotive industry by improving efficiency, accuracy, safety, and environmental sustainability.

In addition, this study justifies the need for realistic RFID Technology and IoT-based Monitoring for Automotive Applications by highlighting the following:

- The automotive industry is constantly evolving, with increasing demand for more efficient, accurate, and sustainable fuelling systems.
- Traditional fuelling systems are often inefficient and prone to errors, resulting in long waiting times, inaccurate data, and safety hazards.
- The proposed smart fuel dispenser system using RFID technology and IoT-based monitoring offers a realistic and feasible solution to these challenges, with proven benefits in other industries such as retail and logistics.

By emphasizing the scientific novelty and the need for realistic and feasible RFID technology and IoT-based monitoring for automotive applications, this study strengthens the argument and makes a compelling case for the proposed system.

6. Conclusion and future scope

6.1 Conclusion

As time plays an important role in day-to-day life in every human activity, none of them wants to waste their time. On the other hand, fuel stations must be manually operated, which takes more time and labour to run. Because fuel is necessary for machines and various vehicles, the need for fuel is growing every day. In the present system, there is a need for a customer to stand in a queue which causes a rush at the fuel stations, especially at the gas pumps; it is very common. Considering all these, this study has attempted to go for an automated fuel dispensing system that eliminates the manual mode of fuel dispensing. RFID technology is also used as a clever automation technique to reduce vehicles waiting time to fill up at fuel stations by shortening the time it takes to dispense the fuel compared to the physical mode of operation. The main theme of this paper is a key way to make systems smarter by utilizing the well-growing platform and communication & information technology. The proposed system proves to be more efficient and reliable by automating the fuel station and making travelling easier for the user. Also, using applications for accessing RFID is a good way to access a card for the user, and they can check the transaction history in the same app is a convenient process. Automated fuel stations make the process more reliable and comfortable for users and service providers. Given the importance of electronics in today's environment, creating new technology for safe fuel distribution and maintaining track of that distribution with the user's permission is crucial. This project aims to transform the current manual data-keeping and dissemination system. Since enterprises can manage distribution and keep track of the same fuel for thousands of miles while sitting in an office, all these operations that a central unit has managed give the right approach to industries' security and economic needs. The major objective is to reduce human involvement and provide a more effective and practical gasoline or fuel-loading design. The following points summarize this paper.

- The proposed smart fuel dispenser system using RFID technology and IoT-based monitoring offers significant advantages over traditional fuelling systems, including increased accuracy, efficiency, safety, and environmental sustainability.
- The implementation of the proposed system has the potential to revolutionize the automotive industry by improving fuelling operations and reducing costs and environmental impact.
- The results of this research provide evidence of the feasibility and potential benefits of the proposed system, but additional research and development are needed to realize its potential fully.

6.2 Future scope

The future scope of this paper outline areas for further research and development of the proposed smart fuel dispenser system using RFID technology and IoT-based monitoring. The following are the future scopes of this study. (i) The need for additional experiments and case studies to evaluate the performance of the proposed system in different contexts and to gather user feedback, (ii) the potential to integrate the proposed system with other technologies, such as machine learning and artificial intelligence, to further optimize fuelling operations, (iii) the need for further research into the economic and environmental impacts of the proposed system, including cost-effectiveness and carbon emissions reductions, and (iv) the potential to expand the proposed system to other industries beyond the automotive sector, such as aviation and maritime.

Enabling a product to future changes can be done because of flexibility. Another possible future scope of the project idea is for the EV industry; it's one of the most promising industries of the future. This same methodology can also be used for charging the electric vehicle (EV) by using appropriate maintenance of battery management and discharge property; developing software can also be an efficient idea to maintain and store the user's details for the service provider's reference. However, note that the charging process for EVs depends on various factors, such as the type of charging station and the involvement of an aggregator. To justify the potential extension of the developed approach to EV charging applications, the researchers should conduct additional research to determine the feasibility of the proposed system in this context. This could include studying the different types of EV charging stations and their technical specifications and evaluating aggregators' potential involvement in the charging process. Moreover, this study could also highlight the potential benefits of using the proposed approach for EV charging applications, such as increased efficiency, accuracy, safety, and environmental sustainability. The proposed system's ability to automate and optimize the fuelling process could also be extended to EV charging, enabling more efficient energy use and reducing the overall environmental impact. To improve the security of the users by providing a biometric facility to enhance overall efficiency. Implementing some of the facilities in the fuel station, including fire alert protection against emergencies, will improve the quality of the fuel station. Adulteration at fuel stations is another issue that may be resolved. Testing for density and evaluating product quality can help with this. With the significant recent deployment of fuel cell electric vehicles and the relevance of the conducted study to hydrogen dispensing systems, the hydrogen vehicle industry might also be introduced into the scenario.

By outlining these areas for future research and development, this paper demonstrates the potential for the proposed smart fuel dispenser system using RFID technology and IoT-based monitoring to have a lasting impact on the fuelling industry and beyond.

Declaration

All authors meet the criteria for authorship as defined by the publisher.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the corresponding author.

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Author contributions

Conceptualization, MP; methodology, MP; software, SC, CJD, KLA and RH; validation, SC, CJD, KLA and RH; formal analysis, MP and LA; investigation, MP and LA; data curation, SC, CJD, KLA and RH; writing—original draft preparation, SC, CJD, KLA and RH; writing—review and editing, MP and LA; visualization, MP and LA; supervision, MP; project administration, MP; funding acquisition, MP and LA. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that they have no conflicts of interest regarding this study.

Nomenclature

CPS: Cyber-Physical Systems
ECC: Elliptic Curve Cryptography
IC: Integrated Circuits
IDE: Integrated Development Environment
ILBSS: Intelligent Location-Based Service System
IoT: Internet of Things
IoV: Internet of Vehicles
JVM: Java Virtual Machine
LCD: Liquid-Crystal Display
PC: Personal Computer
PWM: Pulse width modulation
RFID: Radio Frequency Identification
SDK: Software Development Kit
SQL: Structured Query Language
UI: User Interface
VCC: Vehicular Cloud Computing
XML: Extensible Markup Language

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