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Research Article

Appropriation of RFID Technology in Indian Railway: A Critical Enquiry

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Abstract— India has the fourth-biggest railway networks in the world, with more than 22,593 trains that transport 203.88 million tons of freight and 24 million passengers daily. Under single management, India's railway networks are regarded as one of the biggest in world (Ministry of Indian Railways, 2021). Indian Railways have been a key component of country's transportation system for about 160 years. In India, trains are main means of transportation for both passengers and freight. The most practical and reasonably priced option for both local and long-distance transportation for passengers is the railroad. Railways provide for a number of additional activities, including trade, travel, and pilgrimage, in addition to making it easier to transfer goods across longer distances.

Despite significant advancements, Indian Railways system still faces challenges such as ticketing services, privacy concerns, crowd management, and theft. The high volume of traffic strains operational departments, leading to inefficiencies and increased costs due to unchecked luggage capacity and increased electricity consumption. RFID technology is increasingly utilized in automated societies for contactless transactions, monitoring, and identification, enabling the creation of smart ecosystems through wireless technologies. The present paper suggests that Indian Railways can use wireless sensors and RFID technologies to track passengers and enable online payments using Internet of Things platform. The tracking system uses an RFID reader to locate and trace mobile and passive items linked with passive RFID tags. Every passenger carries an RFID tag as part of proposed system, which includes installing RFID readers at train station's entrances and exits. Passengers may now make payments online thanks to this, and the government can track crowd movements for demand monitoring. This approach establishes digital workplace and ensures that consumers and administration are both following legal safety rules and operational costs are minimised, benefiting both Indian Railways and passengers.

Keywords— Indian Railway, IoT, ticketing services, Contactless digital payment, human safety and privacy, RFID, Operational Efficiency

1. Introduction

In today's society, digitization and digitalization are the latest trend that can be attained by incorporating wireless technology to create intelligent objects [1]. One such smart technology that advances automation wherever it is needed is RFID [2]. RFID technology is more advantageous for tracking and identifying things due to its low cost and ease of implementation [3,4]. RFID allows for the tracking of any object's location through two methods: "tag tracking" and "reader tracking." This study examines the use of tags with RFID for tracking moving items. The chip and antenna that comprise these tags are activated by the radio frequencies that the reader of RFID sends [5]. For the purposes of passenger activity analysis, mapping, and localization, these readers could be placed at each railway station entry and exit [6]. The reader gathers the passenger's information as soon as they arrive at the train station and stores it for later use. This passenger data can be used as the necessary data to analyze customer demand, since customer demand is the most important consideration in any business model's decision-making process. DBSCAN (Density-Based Spatial Clustering of Applications with Noise) algorithm is used to create clustering with high density and noises with a low density in order to categorize the passengers based on their movements and determine their time dependency with regard to the boarding time [7]. Going on to the difficulties encountered in putting the suggested structure into place, the reader's localization of the passengers is more challenging because it must be completed in a certain amount of time. As a result, a reading area that is specifically designed for tag identification without passenger crowding must be established. By doing this, noisy data from signal collisions is avoided [8]. As a result, passenger detection accuracy can be raised, and tracking becomes simple.

This study is of significant importance as it tackles important issues with the Indian Railways system's operational efficiency and passenger management. RFID technology integration offers a creative way to address current inefficiencies in light of the rising demand for smooth and effective transportation networks. The suggested method makes it possible to follow passengers precisely and collect data, which helps with resource allocation, crowd control, and service optimization decision-making. Moreover, by reducing delays, guaranteeing safety, and establishing a more individualized and effective railway environment, the implementation of such a system helps to improve the overall passenger experience. In addition to being in line with worldwide trends in smart transportation, the study shows how automation and digitization can update an outdated system while tackling real-world issues including demand forecasting, data analysis noise, and crowding. The ultimate goal of this project is to create a scalable model that can be applied to other transportation hubs in order to enhance their sustainability and functionality.

The present paper is structured into seven sections. Section 2 comprises of an overview, problems existing in the present system, an assessment of the present system's performance and Introduction of IOT and RFID System including their Types and Components, Advantages and Challenges. Section 3 comprises of the methodology used. The process and advantages of the proposed system is explained in Section 4, along the working model and system requirements. Implementation of RFID in Indian Railways is covered in Section 5. Section 6 presents Major findings and Discussion. Section 7 comprises of the Conclusions and Implications drawn out from this research highlighting unique contributions of this paper. Future scope is explored in Section 8.

2. Literature Review

2.1. Overview

Indian Railways, one of the biggest railway networks worldwide, has significantly improved its services and operations through IT innovation. The Railways Reservation System (IRCTC) allows passengers to book tickets online, making the booking process faster and more convenient. Automatic Ticket Vending Machines (ATVMs) at stations reduce queues and save time. GPS technology is used to track train movements in real-time, improving schedule accuracy and providing real-time updates to passengers [9]. According to India, C. a. Freight Operations Information System in Indian Railways (2010), the Indian Railways introduced the Freight Operations Information System (FOIS), an online platform for managing freight operations, providing real-time information on train movement, loading and unloading status, and wagon availability. Indian Railways utilizes RFID technology for freight train tracking, ensuring safety and security, providing real-time train location information. The Indian Railways has introduced Wi-Fi services on trains and stations, enhancing passengers' internet access and enhancing the overall travel experience according to Ministry of Railways, I. Indian Railways to RFID Tag all wagons by December 2022. Delhi: Press Information Bureau. (2020).

There are numerous methods available for system advancement. IoT opens up new avenues to achieve these ambitious improvements for higher quality of life. RFID technology is employed for ticketing in this new system, therefore it can also be used for tracking [10]. Even though tracking always seems like a privacy violation, controlled use of the collected data with appropriate security can benefit society and the government as predicted [11]. One of crowd control's primary benefits is its capacity to identify passenger behavior [12]. Because it only considers client demand, this data may be categorized and clustered to create a timeline. IoT can therefore be used to manage supply chain management, or SCM, in its final stage. It has been inferred by researchers that all stages of supply chain management (SCM) can be automated by integrating IoT [13]. The storing of supplies and raw materials can benefit greatly from this [14].

2.2. Problems existing in the present system

(a) Currently, most train stations have a computerized ticketing system in place. The tickets are, however, billed by clerical personnel, and the growing population consistently requests more ticket counters, a need that is frequently not satisfied according to Indian Consumer Complaints Forum.
(b) Secondly, lengthy lines in front of reservation offices are a common sight during rush hour in hundreds of train stations around the nation according to Indian Consumer Complaints Forum. Increasing the counter count to solve this problem may cause other problems, such as a shortage of land or an increase in the number of pathways, etc.
(c) Thirdly, because there are multiple trains going to the same place and different classes within each train, there is a need for monitoring.
(d) Lastly, because the existing method utilizes paper for ticketing, a significant number of trees are being lost.

2.3. An assessment of the present system's performance

The use of mobile UTS by passengers has steadily increased, based on data collected from the news release. "UTS on the smartphone app would not just encourage transactions without cash, but it would also guarantee non-contact, effortlessly ticketing," said the general manager of South Western Railway. In December 2021, SWR (South Western Railway) news released an assessment of the performance of the smartphones UTS application contrary to the traditional ticketing systems.

The traveler has two options for booking their ticket: via the UTS (Unreserved Ticketing System) online portal or at the railway's ticket counter. The new system's automated process has a shorter wait time from the beginning to the end [15, 10].

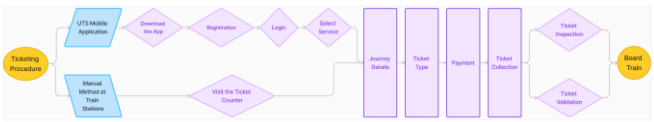

Figure 1. shows the procedure of purchasing tickets at railway stations, either manually or using the UTS phone app.

The current approach distributes tickets within the railway's establishment or via the UTS ticket reservation application, which allows for semi-manual data collection; nonetheless, it is laborious to analyze passenger behavior. On the other hand, in a matter of seconds, the suggested system can compile information about the large quantity of passengers as well as their behaviour.

2.4. IOT and RFID system

2.4.1. Introduction of IOT and RFID technology Automatic technologies known as radio frequency identification systems, or RFIDs, use radio frequencies to assist computers or other electronic devices recognise objects, record metadata, or manage particular goals. The components of an RFID system are typically tags (transmitters/responders) and readers (transmitters/receivers). Tags are an antenna-connected micro-chip that is used to identify an object and can be fastened to it. Both the RFID tag and reader interact via radio waves. As anticipated, RFID has become one of the key information technology opportunities that will significantly and broadly change the globe. When RFID readers that adheres the right protocols are connected to an Internet terminal, readers that are dispersed around the globe can autonomously detect, trace, and surveillance objects that are tagged with tags worldwide in real time. Virtualized replicas of distinctive objects (items) within a Net-like framework are referred to as the "Internet of Things" (IOT). The Internet of Things is frequently considered as requiring RFID. Computers could identify and inventory everyday items if they were all fitted with radio tags [16].

2.4.2. Types and Components of IOT and RFID system

2.4.2.1. RFID systems consist of three primary parts: RFID tags, the reader, and the application system.

(a) RFID tags: Attaching transponders, also called RFID tags (transmitter/responder), to objects allows for measurement or verification. Active or passive tags are both possible. Active tags are those that can run on batteries entirely or partially, can speak with different tags, and start a conversation with the tag reader. Conversely, passive tags don't necessarily need an internal power source because they are fueled by the tag reader. Data storage is the primary function of the microprocessor and helical antenna, which are the primary parts of tags.

RFID tags can be obtained in a selection of forms, sizes, and characteristics; their antenna, integrated circuit, and printed circuit board are necessary components that must be carefully designed while taking commercial and technological requirements into account. An RFID tag's antenna acts as a coupling mechanism upon sending and getting radio waves for communication. It can produce enough energy in the correct conditions to run tag's internal parts without requiring battery. Integrated circuit (IC) of an RFID tag is an independent part that communicates the tag's unique identification. It collects extra data and acts as the master controller for peripheral devices. Depending on the purpose of the tag, the printed circuit board (PCB), which binds it together, can be either stiff or flexible. Usually, tags used for tracking in high temperatures are inflexible [16].

(b) RFID Reader: The reader, sometimes called a transceiver (transmitter/receiver), is made up of a control unit and a radio frequency interface (RFI) module. Activating the tags, arranging the communication sequence with the tags, and exchanging data between the application program and tags.

Interrogators, another name for RFID readers, question tags that are within their read range, facilitating communication and providing information to applications for effective use. Every system consists of two functional blocks: the high frequency interface and the control system, which are regulated by control commands from an external application [16].

(c) Application system: Application systems, also known as data processing systems, can be databases or applications. RFID systems provide a rapid, adaptable, and reliable method for identifying, monitoring, and managing objects. RFID tags emit a unique identifier code, which is sent again to for information gathering reader connected to a data management system. The collected information can be uploaded to a host computer or saved for later use.

Three primary functions of an RFID system are tracking, monitoring, and supervising. In order to spot and alert others to changes, monitoring entails routinely observing particular circumstances. Seeing people or things in motion and providing a model with a timely, sequential sequence of the corresponding location data is known as tracking. Monitoring behaviors, actions, or other evolving data—generally pertaining to humans—is the definition of monitoring. Occasionally it's accomplished discreetly as opposed to much fanfare [16].

Table 1. RFID System Components

Component	Description
RFID Tag	- An object with a transponder attached. - includes an antenna and a microprocessor. - Types include passive (reader-powered) and active (battery-powered).
RFID Reader	- Transceiver(receiver/transmitter). - connects with tags, activates them, and shares information with the application system. - An interrogator is another name for them.
Application System	- system for processing data (such as a database or software program). - Gets and analyzes information from RFID tags. - permits object tracking, observation, and supervision.

2.4.2.2. Internet of Things (IOT)

The Internet of Things (IOT) is an international chain infrastructure that connects virtual and physical things through data collection and transmission capabilities. The provision of specific item recognition, sensing, and connection capabilities will enable the development of autonomous cooperative services and applications. High levels of autonomous data gathering, event transfer, network connectivity, and interoperability will set them apart.

The Internet of Things (IoT) system comprises three layers: the perception layer, the network layer, and the service layer.

The perception layer is responsible for collecting physical world data from various technologies like sensors, tags, and cameras. The network layer facilitates transparent data transmission through access and core networks, providing a reliable network infrastructure platform for large-scale industry applications. The service layer, also known as the data management sublayer, provides directory services, M2M services, QoS, facility management, geomatics, and other services through SOA and cloud computing technologies. It processes complex data and uncertain information, while the application service sublayer converts information into content for high-level enterprise applications and end users, such as supply and logistics, environmental monitoring, disaster alerts, and agricultural management [16, 17, 18].

2.4.3. Advantages of IOT and RFID system

(a) RFID advantages can be briefly explained as follows [19]:

● Without making physical touch or encountering a line of sight issue, a reader is capable of analysing and transmitting data to RFID tags.

● To retrieve data from the numerous RFID tags, the reader uses radio waves.

● RFID is a maintenance-free technology that has been used successfully for over ten years in a range of applications.

● Rapid reading and writing speed, requiring only a few milliseconds for each operation.

● Compared to a standard barcode, modern RFID tags have far larger memory contents, varying from 16 to 64 Kbytes.

● RFID tags are GPRS suitable and have been utilized for tracking.

● Moreover, RFID tags can be integrated with other technologies. Wireless sensor networks, for instance, use RFID tags to improve connectivity.

(b) IOT advantages can be briefly explained as follows: [20]

● IoT technologies enable efficient administration of railway operations by predicting demand, enabling resource management, real-time sensing, intelligent analysis, automated fare gathering, early security alerts, information sharing between stations and trains, freight management, and warehouse administration [21, 22, 23, 24].

● IoT technologies have proven effective in the monitoring, maintaining, and repairing railway portions, sending safety alerts to staff and detecting malfunctions to ensure service continuity for passenger and freight trains [25, 26, 27, 28, 29, 30].

● IoT-based technology can optimize train maintenance by gathering data, processing it, and assigning tasks to relevant staff, thereby preventing future train failures [25, 31].

● By lowering freight theft, fire hazards, and assuring correct maintenance, IoT applications could improve the safety of rail transportation while also boosting competitiveness. [32, 33].

● IoT can enhance service and passenger comfort for railway operators by allocating tasks to available team members, ensuring timely response to traveler demands, and prioritizing needs effectively, such as prioritizing crisis demands over feasting benefit demands. [34, 35].

● Through better management, decarbonization, reduced energy consumption, and increased asset exploitation, IoT-based technologies can transcend present limitations in emissions, energy waste, and greenhouse impacts and help reach sustainable development goals [36, 37].

● IoT-based solutions intensify maglev rail transit systems' performance by monitoring trains, improving safety, and ensuring proper operation through advanced control algorithms and communication technologies [38, 39].

● IoT technology, like cloud computing, sophisticated sensors, and predictive data analytics, expected to enhance automation in rail transportation services without compromising safety.

● Artificial intelligence can improve railways' operational challenges like maintainability, dependability, security, safety, and performance by real-time surveillance, identifying cyberthreats, and resolving decision-making issues like timetabling and resource rescheduling. [40, 41].

Table 2. Advantages of IoT and RFID systems in Railway.

RFID system	IoT system
Reading without contact	Effective management of resources
Rapid reading speed	Increased safety (maintenance, early warnings)
Large capacity of memory	Increased comfort for passengers & Enhanced automation
No upkeep	Enhanced sustainability through lower emissions

2.4.4. Challenges of IOT and RFID System

(a) Key challenges associated with the RFID: [16]

Despite its potential, RFID is not without its difficulties, which come from both a technological and practical standpoint.

● Collision Problems: Electromagnetic interference poses a risk to tag and reader communication, leading to collisions in RFID systems. Effective anti-collision procedures are crucial for large-scale RFID systems. Various protocols, such as FSA, BT, and QT, have been developed for tag identification, but most have an overall efficiency of less than 50%. Uniform distribution of IDs is assumed, which helps identify the best RFID tag identification protocols and develop new ones.

● Security and Privacy Concerns: RFID tags present threats to privacy and security for both persons and businesses. These hazards include denial of service assaults, spoofing, traffic analysis, and eavesdropping. Location privacy may be impacted by unprotected tags since they can be traced by predictable tag answers. The security of RFID technology is restricted by financial and material limitations. To increase applicability, researchers are developing low-cost security and privacy mechanisms. Although there have been some inexpensive remedies put forth, they are not perfect and costly. For low-cost RFID systems, effective ultra-lightweight cryptographic algorithms are required.

● Other Challenges: The biggest obstacles preventing RFID from being widely adopted are three more concerns. The price is the first. Printed labels are still less expensive than RFID tags. Design is the second problem. It is still necessary to engineer readers and tags to ensure extremely trustworthy identification. The incorporation of RFID into current systems presents another difficulty. Creating efficient RFID middleware is important because it connects newer RFID technologis to the back-end infrastructures that already exist. Notwithstanding these difficulties, there will probably be a solution to these issues in due course. RFID has a lot of potential uses; in the future, it will be used for numerous innovative purposes, some of which are impossible to fathom now.

(b) Key challenges associated with the IOT:
In addition to the many benefits that come with IoT application deployment, the current survey has also revealed a number of problems. To ensure the long-term development and deployment of IoT applications in train transit systems and other contexts, relevant parties need to be aware of these obstacles. The highlighted difficulties were further classified into the following groups: operational, privacy and security, standardization, legal, and technological challenges, among other challenges.

(a) Technological challenges: IoT technologies face several technological challenges, including heterogeneity, technology cost, reliable connectivity, appropriate architecture, hardware requirements, and stakeholder involvement. The diverse applications of IoT devices require different networking capabilities and security countermeasures. The cost of IoT communication technologies such as power line communications, wireless, mobile, and fixed communication systems, should be reasonable to avoid negative impacts on adoption. Reliable connectivity is crucial for effective deployment. The variety of IoT devices and the complexity of IoT services make it difficult to design an IoT architecture that works well in one domain. Hardware requirements may vary due to bandwidth differences, and achieving low power consumption and cost is a major issue. Stakeholder involvement is also essential for successful IoT solutions, requiring new cooperative methods to promote communication among stakeholders. [42, 43, 44, 45, 46, 47]
(b) Operational challenges: The Internet of Things (IoT) faces numerous operational difficulties, including scalability, interoperability, networking, adaptability, application maintenance, and real-time response. Scalability is crucial for managing the sustainable growth of IoT technology, as devices are often placed in hierarchical sub-domains. Interoperability requires innovative holistic approaches across different tiers, such as physical, functional, communication, and application layers. Networking can be challenging due to influenced protocols and information flow, and predicting the best location for IoT devices can be challenging. Adaptability is essential for IoT systems to function in changing environmental conditions. Application maintenance is crucial for IoT applications to service wide geographic areas with dynamic surroundings. Real-time response is essential for IoT domains like healthcare, telemedicine, disaster response, and vehicle-to-vehicle communication, as delayed responses can lead to negative externalities. As a result, future IoT systems that enable time-sensitive domains need to be properly developed and implemented. [42, 43, 20]

(c) Privacy and security challenges: The Internet of Things (IoT) faces numerous privacy and security challenges in IoT design include data confidentiality, threat detection, authentication, countermeasures, and user awareness trainings. Security is a crucial aspect of IoT design, affecting hardware and software characteristics. Devices must undergo extensive testing to ensure adequate response to cyber-attacks. Data confidentiality and integrity are essential for IoT applications, ensuring only authorized individuals can access and modify data. Threat detection is a major challenge, necessitating the development of new algorithms to identify potential security breaches. Authentication is crucial for IoT systems, ensuring only authorized users can access them. Countermeasures, such as intrusion prevention, intrusion detection, IP security, encryption, and authentication, are needed to combat various attacks. As IoT devices grow, new countermeasures are needed to protect against malicious attacks. User awareness trainings are also crucial to ensure future users understand the security measures and potential vulnerabilities of IoT technology. [48, 43, 20]

(d) Standardization and legal challenges: Standardization and legal challenges involve standardization and modifying existing laws and regulations. Standardization is crucial for IoT system development and deployment, allowing easy access and use for all actors. It is anticipated that international standards will be more effective than regional ones. Existing laws and regulations are limited, slow, and too instrumental for IoT technology development. Changes in laws, sanctions for violations, and global accountability are needed for next-generation IoT systems. [20, 44]

(e) Other challenges: Other challenges include business, global cooperation, ethical, ecological, human interactions, and user perception and confidence. The selection of the right business model and application scenario for IoT-based applications is complex due to uncertainties. Global cooperation challenges arise from coordinating IoT infrastructure investments across different approaches, addressing short- or mid-term return on investment. Stakeholders must handle ethical concerns such confidential recording, needless data gathering, secondary usage, personal data leaking, and intellectual property rights. Ecological issues like waste, high power consumption, and short battery life must be addressed. Internet of Things applications require human input for functionality, but complex human-device interactions are challenging to predict accurately. To improve interactions and imitate human behavior, new methods are needed. Consumers may be concerned about IoT devices' functionality in disruptive situations and safety issues. New educational initiatives and future user participation can enhance user perception and confidence in IoT technology. [20]

3. Methodology

In order to solve current inefficiencies and improve operational capacities, the methodology for this study is concentrated on putting forth a conceptual framework for incorporating RFID technology inside the Indian Railways system. The methodology entails a thorough examination of the shortcomings of the current system, which is followed by a thorough investigation of RFID and IoT technologies, including their types, constituents, benefits, and related difficulties. The study places a strong emphasis on comprehending how these technologies can be used to build an intelligent ecosystem for data-driven decision-making and passenger tracking.

An extensive literature review was carried out to obtain information about current RFID applications in transportation systems and other industries in order to construct the suggested framework. The design of the suggested system, which describes the steps and features of RFID integration, including the positioning of RFID readers at key points of entry and departure, data gathering techniques, and the use of the DBSCAN clustering algorithm for passenger activity analysis, was influenced by this review. To illustrate viability and possible advantages, a conceptual explanation of the working model and system needs is provided.

The suggested implementation strategy emphasizes resource optimization, crowd control, and improved passenger convenience as it focuses on how RFID technology can be smoothly integrated into the Indian Railways system. Despite not involving the system's actual creation or implementation, this study offers a thorough analysis of its theoretical ramifications, tackling operational and technical issues to guarantee real-world relevance. This conceptual inquiry yielded discoveries, conclusions, and future scope that provide a basis for additional research and practical application.

4. Process of proposed system

Passengers who register their distinct RFID through the UTS mobile application initiate the procedure of the proposed system. The following step involves validating and verifying the user details. All of the information is then kept in the database, which is often located on the cloud. The services rendered to the traveller determine which data are retrieved. In this case, the traveller utilizes the RFID tag in place of a transit card to travel by train. As a result, only the information needed for ticketing is retrieved and processed.

The procedure starts with user registration and continues with user data processing according to the services the client has requested. Depending on the information received for the necessary service, the customer is either the government or the traveller. Additionally, data analytics can be used for a variety of reasons to forecast and identify a way to improve the system in numerous ways.

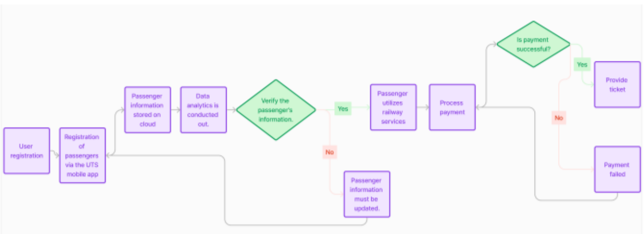

Figure 2. shows the flow diagram for user verification.

Every passenger's unique detail is taken into account when creating the high-demand cluster. The analysis's findings allow for the classification of the passengers into three groups: habitual passengers who don't follow any patterns, irregular passengers who travel on regular routes but with unpredictable schedules, as well as regular passengers who follow schedules. This aids the government in providing for the needs of those in strong demand, at during the busiest times.

4.1 System requirements and Working model

The technical specifications of the suggested system include the RFID reader and tag, a database to store passenger data, a host computer to manage environment-wide operations, and a data analytics tool to handle demanding upgrades investigate further. Once the RFID reader has read the passenger data, an Arduino UNO integrated in the reader processes the data. These data are kept on cloud servers, and only the information that is needed is retrieved in response to passenger requests.

Everyone seeking to use the railways must have an RFID card, according to the system. A portable, wireless gadget with a card reader would power a ticket checker during the travel procedure. It would be expected of every passenger to present their cards for the checker to swipe. The device may show the traveller's identity, date of birth, gender, and card number as they are swiping. Furthermore, the travelling chronology, available balance before to swiping, and reservation status could all be shown. The exact amount may be calculated if the checker entered the destination codes. The benefit of using wireless technology to improve the current system and make it more dependable and adaptable is further enhanced by the consideration that all railway platforms are already interconnected. Also, since the card can be pre-credited with funds and deductions made accordingly, the concept of a physically printed ticket serving as a middleman go-between for payment and the journey may be abandoned. Since most of the processes outlined currently have the necessary technology and infrastructure in place, making these improvements would not be difficult and would benefit the country greatly.

First, the traveller is given a unique RFID tag that serves as a lifelong ticket for train travel. This tag is linked to a unique ID in the current UTS mobile application, which already has general passenger information like identity, date of birth, sex, and place of residence that can be obtained from any government-issued ID that has been submitted for KYC (Know Your Customer). The passenger must recharge their transit cards in order to obtain tickets when this process is finished. Passengers can register their source and destination in the program whenever they need to use trains for commuting. The application wallet will be emptied of the necessary amount to cover the chosen journey. Once the passenger has completed the online process, they can continue with their journey. Most importantly, this procedure can be carried out from any location within a 5-kilometre radius of the source station at any time up to one hour prior to the start of the trip.

Passengers use RFID tags to log their travel information, which is then scanned by RFID readers at train stops. Later, when the user requests it, the reader data pools are used for analysis. Numerous procedures occur between data connectivity and data analytics. Since user data and client activities on the data are classified, data encryption is done to secure the shared resources. Once the data has been retrieved from the cloud, the analytics platform of choice should be utilized to replicate the intended outcomes. In order to enhance user services, government representatives might share some of the sample results with individuals and use them to upgrade the system.

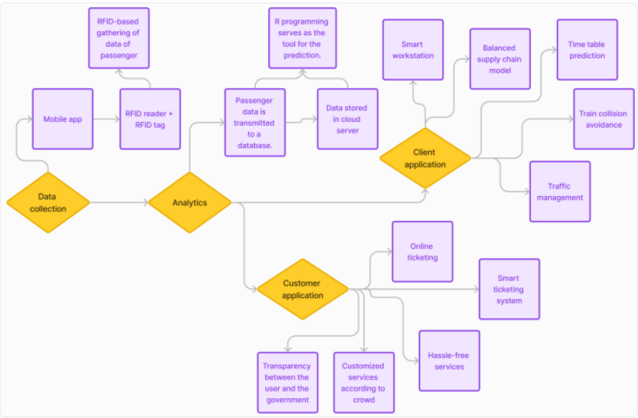

Figure 3. shows the three stages of the suggested system's process.

The automated ticketing system's results are improved through the examination of passenger behavior in transit. Using an adapted DBSCAN algorithm taken from the current model, this entails subdividing each type of passenger into groups according to various transfer customs, destinations and modes of transportation, kinds of cards, and frequency of utilization [49]. Essentially, the goal is to use the extensive data on passenger kinds to gain a deeper understanding of clusters, their unique needs, and the skills required for efficient service delivery. It is evident that the current approach uses trip pattern analysis to categorize passengers by recreating their itineraries [50]. Thus, the history of the journey along with the passengers' timestamps is mined for spatial and temporal data.

The suggested approach builds a more effective method of arranging data points in space by combining an algorithm for unpredictability KD-Tree Using DBSCAN. The algorithm must operate in high-dimensional spaces while working with public data, solving the challenges of mapping the queries with the appropriate locations to produce the intended result in the quickest amount of time for decision-making. Here, the iDBSCAN method performs admirably.

4.2. Advantages of the proposed system

(a) Since the card would include a picture of the bearer on it, the identification issue would not be an issue. To make things even more safe, they may also use a key that only the cardholder should know.

(b) Thanks to changes made to the touch screen computers that are available in the stations and on the Railways website, passengers may now see their travel history and credits.

(c) As part of the visa application process, foreign visitors to the nation may be granted a temporary card, allowing legitimate travellers to journey and denying terrorists access to the core of our transportation network. People would not be able to use this service once their visa has expired thanks to such a system, since the details will be

5. Implementation of RFID in Indian Railways

Indian Railways are embracing RFID technology. Currently, they use it to track rolling stock (coaches and wagons) for better management, but its potential extends to the ticketing system. Implementing RFID in ticketing could lead to faster boarding times, better fraud detection, and improved resource allocation - all translating to cost savings. Here's a breakdown of key areas:

5.1 Current Implementation:

Indian Railways are already utilizing RFID for rolling stock management. Tags attached to coaches and wagons allow for real-time tracking, improving efficiency and visibility.

5.2 Potential for Ticketing:

Extending RFID to ticketing systems offers numerous benefits:

(i) Reduced Costs: Faster ticketing and boarding, improved fraud detection, and optimized resource allocation can lead to significant cost savings.
Increased Revenue: Reduced ticket evasion translates to higher revenue collection.

5.3 Challenges and Considerations:

(a) Return of Investments (ROI) of implementation cost of RFID in Railway:

(i) Initial Investment: Implementing RFID for ticketing in Indian Railways requires a significant initial investment. The cost breaks down into three main categories:

- Tags: Passive UHF tags, used for tracking passengers, cost around Rs 3 per unit in bulk quantities according to encstore.com.
- Readers: The price of RFID readers varies depending on their reading range and capabilities. These can range from a few thousand rupees to lakhs of rupees, and equipping both stations and trains will be a substantial upfront cost according to encstore.com.
- Back-End Infrastructure: Developing and maintaining the system for data storage, management, and integration with existing ticketing systems necessitates further investment. This includes the software, hardware, and ongoing maintenance required for the smooth operation of the RFID system.

(ii) Operational Costs:

- System Maintenance: Regular maintenance of tags, readers, and IT infrastructure would incur costs.

- Data Management: Storing and analyzing the large amount of data collected by RFID systems would require ongoing expenses.

(b) Benefits of implementation:
(i) Reduced Operational Costs:

- Faster Ticketing and Boarding: RFID can automate ticket verification, reducing queues and staff needed for manual checks.
- Improved Fraud Detection: RFID tags are more difficult to forge compared to paper tickets, reducing ticketless travel and revenue loss.

Enhanced Inventory Management: Real-time tracking of passenger flow and occupancy can optimize resource allocation.

(ii) Increased Revenue Collection:

- Reduced Ticket Evasion: RFID makes it harder to avoid fares, potentially increasing revenue.

(c) Employment Impact of implementing RFID in Indian Railways:
While Indian Railways boasts the second-highest public sector employment in India, the overall impact of RFID implementation on jobs is expected to be minimal according to wikipedia. While some roles might face automation with RFID, the technology is more likely to create new opportunities and improve efficiency. Strategic reskilling programs can further support this transition.

5.4 New Opportunities:
RFID implementation opens doors for new roles such as:

- **RFID system technicians:** Installation, maintenance, and troubleshooting of tags, readers, and back-end systems.
- **Data analysts:** Extracting insights from the vast amount of data for improved operations, resource allocation, and inventory management.
- **Security specialists:** Ensuring data and system security against breaches.
- **Customer support specialists (RFID):** Assisting passengers with using the system and troubleshooting issues.
- **RFID system integration specialists:** Coordinating the integration of RFID with existing railway management and ticketing systems.
- **Project managers (RFID implementation):** Overseeing the groundwork, deployment, and maintenance of the RFID ticketing system across the vast network.
- **Business intelligence analysts (RFID):** Utilizing data to generate insights for improved operational efficiency, resource allocation, and marketing strategies.

5.5 Potential Job Displacement:
A small number of positions might be affected by automation:

- **Manual ticket checkers:** Tasks like ticket verification could be automated with RFID readers.
- **Train marshalling staff (if automated):** Some aspects of train shunting and yard management might be automated in the future.
- **Security and Housekeeping Staff (partially):** Roles in access control and manual security checks might be streamlined with enhanced RFID security.
- **Reservation Clerks (partially):** Simple reservation tasks like confirmation and basic inquiries could be streamlined.
- **Platform Staff (partially):** RFID-based passenger guidance and announcements could reduce some platform staff involvement.
- **Train Ticket Examiners (partially):** Onboard checks might become more efficient with RFID, potentially reducing check frequency.

5.6 Balancing the Act:
The massive workforce of Indian Railways (over 1.2 million) suggests that potential job displacement will be relatively small compared to the overall number of employees. New opportunities created by RFID are likely to balance out any job losses. Additionally, upskilling and reskilling programs can support the existing workforce in transitioning to new roles involving RFID technology.

6. Major Findings and Discussion

By classifying customers according to their travel habits, the suggested solution not only streamlines the ticketing process but also offers a reliable technique for data-driven decision-making. By customizing their services to meet the requirements of various passenger groups, transportation authorities can increase overall efficiency and satisfaction. For example, knowing regular passenger patterns guarantees the availability of timely, reliable services in high-demand locations and improves resource allocation. Similar to this, pinpointing areas where a substantial percentage of passengers are irregular might reveal possible service quality gaps and allow for focused enhancements to increase accessibility and convenience for this demographic.

Additionally, real-time data collection made possible by the integration of RFID and IoT devices can be examined to forecast changes in demand and improve service schedules. This feature greatly improves passenger flow and crowd management by easing congestion during peak hours. Furthermore, by using data analytics, transit authorities may find and fix inefficiencies like congested stations or underused routes, guaranteeing that resources are allocated efficiently.

Personalized services like dynamic ticket pricing or trip suggestions based on past passenger data are also possible with this technology. Through customized services and promotions, this strategy not only increases passenger pleasure but also opens up chances for more revenue. Authorities may create a more inclusive and equitable transit system by utilizing the descriptive insights gained from passenger categorization. This will guarantee that the demands of all passenger kinds are satisfied and promote the railway network's long-term sustainability and expansion. The suggested solution uses mobile applications and Internet of Things devices for online ticketing. Additionally, predictions could be made using the environmental data that has been acquired. Utilized in the environment are physical devices such as RFID, Arduino, and a host computer.

With the following benefits, the Indian Railways System, based on IoT, introduces the idea of an online ticketing system for passengers:

- Shorter wait times
- Handling large crowds
- Easy-to-use ticketing
- Less effort and documentation for the government

Depending on the needs of the user, the obtained data can be used for a variety of analysis. Thus, RFID and Arduino combine to simplify and ease the process of data collection.

In order to distinguish between different passenger kinds, present paper classifies passenger travel characteristics into geographical and temporal travel patterns. The following three passenger bunches emerge:

- Regular Passengers: Those who travel on regular schedules and routes are classified as such. Their itineraries and routes stay the same.
- Irregular Passengers: Passengers who travel at unpredictable times but on consistent routes are known as irregular passengers. These travellers travel regular routes rather than sticking to set time slots.
- Habitual Passengers: Passengers that travel in a habitual manner fall into this category. They don't follow any particular temporal or spatial patterns. They don't have regular routes or hours for travel.

Three simple considerations form the basis of the categorization:

- Consideration 1: A passenger is categorized as irregular if no discernible temporal or spatial travel pattern can be found.
- Consideration 2: A passenger is considered a regular passenger if more than 50% of their trips take place on regularly scheduled times and routes.
- Consideration 3: The remaining passengers are classified as regular travellers.

The descriptive data for every kind of passenger, adds important context to the passenger profile. A thorough grasp of each passenger category and important insights into their traits could be obtained from the analysis of passenger categorization. Understanding the entire service needs for each region can be gained by characterizing passenger demand according to the percentage of each kind. A high concentration of irregular passengers may point to problems with the quality of the transit service offered, whereas a regular passenger area requires timely services. By attracting more high-value clients, like transit users, governing bodies can strengthen revenue and encourage transit-oriented initiatives. To preserve consumer equity and the system's general appeal, it is crucial to attend to the demands of other passenger kinds as well. This section offers doable service enhancements that make use of the understanding of passenger classification. Having a thorough understanding of each type of customer helps transit authorities plan strategically, which enables the creation of transit-on-demand services to serve people who need to travel frequently but cannot use traditional routes.

7. Conclusions and Implications

7.1. Conclusions

The implementation of an RFID-based ticketing system in Indian Railways can lead to significant improvements in ticketing efficiency, passenger experience, and operational costs. The system can be integrated with existing infrastructure and can pave the way for future developments in RFID technology in the railway system. The proposed system has the potential to transform the ticketing system of Indian Railways and enhance the standard of nationwide transportation overall.

The present research demonstrates a system's characteristics when a portion of it is automated using Internet of Things enabling technologies. Despite decades of manual data collection and processing, the integration of IoT with commonplace objects has exposed people to the concept of smart items. Forthcoming, the integration of IoT technologies is triggered by the procedure carried out and measured in this study. The payment system's autonomous processing environment is completely changed when sensors and actuators are integrated with the current setup. Online payments that are completely contactless are now available for effective crowd management. Various studies can be performed on the raw data collected, depending on the needs of the user. Numerous more subsequent papers explored novel strategies and methods for developing smart cities.

7.2. Implications of the technology

- Contactless payment systems [51]
- Real-Time Information Display System [52]
- Smart bag tracking and alert system [46]
- Identification, Positioning, Looping and Obstacles Detection of Railways [53, 54]
- Inspection of Railway Tracks [53, 55, 56]
- Proper operation of rolling stock [53]
- Train Axle Temperature Measurement System [53]
- Train overspeed protection system [53]
- Railway Accident Prevention and Monitoring System [57]

8. Future scope

The deployment of RFID technology in the ticketing system of the Indian Railways is just the beginning of a larger transformation. The use of RFID technology can open up new possibilities for the railway system, such as real-time monitoring of passenger traffic, automatic fare collection, and predictive maintenance. Additionally, RFID technology can be implemented with other cutting-edge innovations like Internet of Things and artificial intelligence to develop smart railway system that can optimize its operations, improve passenger experiences, and reduce its environmental footprint. The future possibilities of RFID technology in Indian Railways are endless, and it is up to the railway authorities to harness its full potential.

Data Availability

Since the main focus of this research is the proposal of a system rather than its implementation, the data used to support the study's results are drawn from theoretical and conceptual frameworks. There is no empirical data available for publication because the system has not been designed or implemented. Data will be gathered and shared in accordance with privacy laws and ethical standards in future research including real-world application.

Limitations of the Study:

The study is conceptual in nature and lacks field testing and actual application, which restricts the validity of the suggested system's efficacy. If the system were put into place, the following possible drawbacks might have a major influence on research findings:

- Technical Restrictions: Issues with RFID infrastructure deployment, like interoperability with current systems.
- Data Accuracy: Possible errors in data gathering brought on by external variables like as signal collisions, reader sensitivity, and interference.
- Privacy Concerns: Making sure that passenger data is secure and that legal privacy rules are followed.
- User Adoption: Opposition from users who are not accustomed to digital technology, particularly in areas with lower levels of digital literacy.
- Maintenance: In a variety of environmental circumstances, IoT devices and RFID tags require a high level of maintenance.

The study restrictions would therefore be regarded as inconsequential if none of these factors apply in subsequent research settings.

Conflict of Interest

The author affirms that there are no financial or other conflicts of interest that could improperly affect or be seen as influencing the study's findings and content. Without prejudice or outside influence, the research is carried out and presented exclusively for the purpose of advancing academically and professionally.

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Authors' Contributions

The author, Srushti J. Patil, is the sole contributor to this research manuscript. She was responsible for conceptualizing the study, designing the proposed system, conducting the literature review, and writing the entire paper. The research methodology, analysis, and discussion of findings were all written independently. As there are no co-authors, all aspects of the paper, including the formulation of ideas and structuring of the manuscript, reflect the author's individual work.

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References

[1] Garrido-Hidalgo, Celia & Hortelano, Diego & Roda-Sanchez, Luis & Olivares, Teresa & Ruiz, M. Carmen & Lopez, Vicente. "IoT Heterogeneous Mesh Network Deployment for Human-in-the-Loop Challenges Towards a Social and Sustainable Industry 4.0." IEEE Accesss, pp.**1-10.1109, 2018.**

[2] Li N, Tan J, Zhu Z. "Monitor and control system with RFID technology in discrete manufacturing line". Proceedings of the IEEE International Conference on RFID-Technology and Applications, Guangzhou, China. pp.**71–76, 2010.**

[3] Sudhakaran, S., Maheswari, R. and Kanchana Devi, V. (2024) 'An improvised analysis of smart data for IoT-based railway system using RFID', Automatika, Vol.**65**, Issue.**1**, pp.**361–372, 2024**

[4] Shukoor MA, Mukeshbhai SS, Dey S. "12-Bit multiresonator based chipless RFID system for Low-cost item tracking", Proceedings of the 2021 IEEE International Conference on RFID Technology and Applications (RFID-TA), pp.**136–138, 2021.**

[5] A. Subrahmannian and S. K. Behera, "Chipless RFID: A Unique Technology for Mankind," in IEEE Journal of Radio Frequency Identification, Vol.**6**, pp.**151-163, 2022**

[6] X. Zhang, V. Lakafosis, A. Traille and M. M. Tentzeris, "Performance analysis of "fast-moving" RFID tags in state-of-the-art high-speed railway systems," 2010 IEEE International Conference on RFID-Technology and Applications, Guangzhou, China, pp.**281-285, 2010.**

[7] S. Li, "An Improved DBSCAN Algorithm Based on the Neighbor Similarity and Fast Nearest Neighbor Query," in IEEE Access, Vol.**8**, pp.**47468-47476, 2020.**

[8] W. -L. Wang, C. T. Huang and B. -T. Ke, "An Algorithm for RFID Signal Collision with Meridian Theory," 2012 International Symposium on Computer, Consumer and Control, Taichung, Taiwan, pp.**725-728, 2012.**

[9] Kumar, Chinmoy. (2006). "Indian Railways: IT Innovations in Passenger Services". In P. kumar, Indian Railways, seva books, pp.**161-170, 2008.**

[10] A. A. Nunes, T. Galvão Dias and J. Falcão e Cunha, "Passenger Journey Destination Estimation From Automated Fare Collection System Data Using Spatial Validation," in IEEE Transactions on Intelligent Transportation Systems, Vol.**17**, No.**1**, pp.**133-142, 2016.**

[11] C. C. Tan, Qun Li and Lei Xie, "Privacy protection for RFID-based tracking systems," 2010 IEEE International Conference on RFID (IEEE RFID 2010), Orlando, FL, pp.**53-60, 2010.**

[12] M. Yamin and Y. Ades, "Crowd Management with RFID and Wireless Technologies," 2009 First International Conference on Networks & Communications, Chennai, India, pp.**439-442, 2009.**

[13] R. Behl and S. Dhir, "Role of IOT in Supply Chain Innovation: A Survey Analysis," 2022 International Mobile and Embedded Technology Conference (MECON), Noida, India, pp.**33-36, 2022.**

[14] Tripathy, Rudra Prasad, Manoj Ranjan Mishra, and Satya Ranjan Dash. "Next generation warehouse through disruptive IoT blockchain." In 2020 International Conference on Computer

Science, Engineering and Applications IEEE (ICCSEA), pp.**1-6, 2020.**

[15] Datta, Prerit, Namandeep Kaur, and Naveen Garg. "Automatic Bus Fare Collection System in India." In Information Systems Design and Intelligent Applications: Proceedings of Second International Conference INDIA, Springer India, Volume 2, pp.**681-689, 2015.**

[16] X. Jia, Q. Feng, T. Fan and Q. Lei, "RFID technology and its applications in Internet of Things (IoT)," 2012 2nd International Conference on Consumer Electronics, Communications and Networks (CECNet), Yichang, China, pp.**1282-1285, 2012.**

[17] Arun Kumar Singh & Alak Kumar Patra “Cybersecurity Support in IoT: Causes and Solutions in Engineering” International Journal of Scientific Research in Multidisciplinary Studies Vol.10, Issue.5, **pp.107-119, 2024**.

[18] Ganesh Marrivada “Securing Digital Identity: The Convergence Of Cybersecurity And Iam In Contemporary Organizations” International Journal of Computer Engineering and Technology (IJCET) Vol.**15**, Issue.**6**, pp.**1431-1439, 2024.**

[19] R. Want, "An introduction to RFID technology," in IEEE Pervasive Computing, Vol.**5**, No.**1**, pp. **25-33, 2006**.

[20] Prashant Singh, Zeinab Elmi, Vamshi Krishna Meriga, Junayed Pasha, Maxim A. Dulebenets, “Internet of Things for sustainable railway transportation: Past, present, and future” Volume 4, 100065, ISSN 2772-3909, **2022.**

[21] Li, W., Chen, Z.H. and Sui, L.Y., “Design and Application of Mass Passenger Flow Precautionary and Forecasting System in Rail Transit Based on the Internet of Things Technology”. In Applied Mechanics and Materials, Trans Tech Publications Ltd. Vol. 556, pp.**6366-6369, 2014**.

[22] R.X. Zhang, Z.Y. Liu, J.W. Guo “ Research on application of internet of things technology in railway transportation” J. Railway Eng. Soc., 10, pp. **021, 2011.**

[23] Lei, X., Wang, X.F. and Li, L. “Railway information integration and sharing mode researching based on internet of things”. In Advanced Materials Research, Trans Tech Publications Ltd., Vol. 694, pp. **3353-3356, 2013.**

[24] Shi, L. and Wang, X.F., 2013. “Design of Railway Information Platform Based on the Internet of Things”. In Advanced Materials Research, Trans Tech Publications Ltd., Vol. 694, pp.**3345-3348, 2013.**

[25] Zhang, W., “Study on internet of things application for high-speed train maintenance, repair, and operation (MRO)”. In Proceedings of the National Conference on Information Technology and Computer Science (CITCS 2012), Lanzhou, China, pp.**16-18, 2012.**

[26] Chapman, L., Warren, E. and Chapman, V, “Using the internet of things to monitor low adhesion on railways”. In Proceedings of the Institution of Civil Engineers-Transport, Thomas Telford Ltd., Vol.**169**, No.**5**, **pp.321-329, 2016.**

[27] Karaduman, G., Karakose, M. and Akin, E. “Condition monitoring platform in railways based on IoT”. In 2018 IEEE International Conference on Artificial Intelligence and Data Processing (IDAP), pp. **1-4, 2018.**

[28] T. Shankar, G. Yamuna, E.B. Elanchezhian “Advanced landslide surveillance system for railway transport accident avoidance using Internet of Things (IoT)” J. Comput. Theor. Nanosci., 16 (4), pp. **1701-1705, 2019.**

[29] A. Mohamed, Q. Peng, M.M. Abid “Integrated maintenance logistics monitoring system for high-speed rail, based on internet of things technology” Eur. TransportTrasporti Europei, 2020 (75–6), pp. **1-10. 2020.**

[30] Duan, L., Liu, J. “Smart composite materials and IoT: Revolutionizing real-time railway health monitoring”. MRS Communications (2024).

[31] G. Zhong, K. Xiong, Z. Zhong, B. Ai “Internet of things for high-speed railways” Intelligent Converged Networks, 2 (2), pp.**115-132, 2021.**

[32] .H.A.O. Ling “Design of railway freight transport security system based on internet of things” J. Chongqing Univ. Technol. (Natural Science), 6, pp.**025, 2013.**

[33] J. Zhang, L. Shao “An applied study on railway safety monitoring based on internet of things” J. Logistics, Inf. Serv. Sci., 1 (1), pp.**1-11, 2013.**

[34] Gangwar, N., Semwal, T., Nair, S.B., “CARE: An IoT based system for passenger service and comfort in railways”. In 2017 9th IEEE International Conference on Communication Systems and Networks (COMSNETS), pp.**55-62, 2017.**

[35] A. Ganga, J.K. Periasamy, N. Gopinath, D. Sathishkumar “IoT based passenger comfort and services in railways” Int. J. Recent Technol. Eng., 8 (4), pp. **7081-7084, 2019.**

[36] O.O. Adebiyi, M. Cruz “Green sustainability development for industry internet of things in railway transportation industry” Int. J. Trend Sci. Res. Develop., 3 (1), pp.**203-208, 2018.**

[37] Solanki, A. and Nayyar, A. “Green internet of things (G-IoT): ICT technologies, principles, applications, projects, and challenges”. In Handbook of Research on Big Data and the IoT, IGI Global, pp.**379-405, 2019.**

[38] M. Kumar, S. Arora, A. Verma “IoT remote tracking and increased adaptive fluctuating operation of the maglev train network medium-low speed train” Int. J. Adv. Res. Eng. Technol., 11 (12), pp.**1724-1729, 2020.**

[39] Y. Sun, H. Qiang, J. Xu, G. Lin “Internet of Things-based online condition monitor and improved adaptive fuzzy control for a medium-low-speed maglev train system” IEEE Trans. Ind. Inf., 16 (4), pp.**2629-2639, 2020.**

[40] F. Flammini, V. Vittorini, and Z. Lin, “Roadmaps for AI Integration in the Rail Sector – RAILS”, ERCIM News, no. 121, pp.**34–35, 2020.**

[41] Voronko, I. “The security of IoT systems in railway transport. Transport Systems and Technologies”, (43), pp.**90–99, 2024.**

[42] S. Chen, H. Xu, D. Liu, B. Hu, H. Wang. “A vision of IoT: Applications, challenges, and opportunities with china perspective” IEEE Internet Things J., 1 (4), pp.**349-359, 2014.**

[43] Z.H. Ali, H.A. Ali, M.M. Badawy. “Internet of Things (IoT): definitions, challenges and recent research directions”, Int. J. Comp. Appl., 128 (1), pp.**37-47, 2015.**

[44] Y. Chen, F. Han, Y.H. Yang, H. Ma, Y. Han, C. Jiang, H.Q. Lai, D. Claffey, Z. Safar, K.R. Liu “Time-reversal wireless paradigm for green internet of things: An overview IEEE Internet Things” J., 1 (1), pp.**81-98, 2014.**

[45] J. Gubbi, R. Buyya, S. Marusic, M. Palaniswami. “Internet of Things (IoT): A vision, architectural elements, and future directions. Future Generation Computer Systems”, 29 (7), pp.**1645-1660, 2013.**

[46] Sarkar, Shubham, Suvojit Manna and Subhadeep Datta. “Smart bag tracking and alert system using RFID.” 2017 International Conference on Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICEECCOT), pp. **1-4, 2017.**

[47] I.S. Udoh, G. Kotonya. “Developing IoT applications: challenges and frameworks”. IET Cyber-Phys. Syst.: Theor. Appl., 3 (2), pp.**65-72, 2018.**

[48] Mohamed, Litoussi & Kannouf, Nabil & El Makkaoui, Khalid & Ezzati, Abdellah & Fartitchou, Mohamed. “IoT security: challenges and countermeasures”. Procedia Computer Science. 177. pp.**503-508, 2020.**

[49] Koppikar U, Hiremath S, Shiralkar A, et al. “Iot based smart attendance monitoring system using RFID”, Proceedings of the 2019 1st International Conference on Advances in Information Technology (ICAIT); pp. **193–197, 2019.**

[50] L. M. Kieu, A. Bhaskar and E. Chung, "Passenger Segmentation Using Smart Card Data," in IEEE Transactions on Intelligent Transportation Systems, Vol.**16**, No.**3**, pp.**1537-1548, 2015.**

[51] Lacmanovic, Izabela, Biljana Radulovic and Dejan Lacmanovic. “Contactless payment systems based on RFID technology.” The 33rd International Convention MIPRO, pp.**1114-1119, 2010.**

[52] Ramesh, R., G. Divya, N. Thomas, A. Varghese, and L. Mahendran. "Real-Time Information Display System for Indian Railways Using RFID." Journal of Network and Information Security Vol.**5**, No.**2**, pp.**23–25, 2017.**

[53] Malakar, Bidhan and Binoy Krishna Roy. “Survey of RFID applications in railway industry.” 2014 First International

Conference on Automation, Control, Energy and Systems (ACES), pp.**1-6, 2014.**

[54] S. D. N, S. V, S. L, S. G and P. M. R, "An IoT Framework for Effective Railway Looping and Obstacles Detection," 2024 International Conference on Inventive Computation Technologies (ICICT), Lalitpur, Nepal, pp.**1814-1818, 2024**.

[55] S. Janani, S. Vijayaram and R. C. Vijayganesh, "IoT-SafeRails: Revolutionizing Railway Collision Avoidance Technology," 2024 International Conference on Inventive Computation Technologies (ICICT), Lalitpur, Nepal, pp.**1666-1673, 2024.**

[56] J. N. L. A, L. Narayanan C, K. M. S, R. S and K. R, "Railway Track Crack and Key Detection Robot using IoT," 2022 International Conference on Edge Computing and Applications (ICECAA), Tamilnadu, India, pp.**623-628, 2022.**

[57] Narsaiah, M.N. & Reddy, Sudugu & Kavya, Eppalapalli & Pavani, Uppu & Shivasai, Badha & Lavanya, C. & Kaur, Namita, "Prevention Of Train Collision Using GPS Based Tracking System", MATEC Web of Conferences, pp.**392-10.1051, 2024.**

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Her academic journey and professional experiences reflect her proficiency in interdisciplinary design, where she integrates principles from interaction design, system design, and human-centered design. In addition to her academic and design-focused work, she has gained industry experiences in the field of Interaction Design (UX/UI), Visual Communication Design (Brand Strategy & Management, Graphic Design, etc), and various aspects of strategic and responsive design. She is dedicated to continuous research, driven by a passion for making groundbreaking and innovative contributions to the field of design. Her ability to drive innovative thinking is evident through the funded projects and grants she has received, showcasing her exceptional mindset and ability to merge design with technology, and problem-solving. Her research skills are grounded in her thorough understanding of user-centered methodologies, data analysis, and a keen focus on human behavior and psychology. Her research enables her to investigate, analyze, and solve complex problems, ensuring her works contribute to the development of systems that are both functional and meaningful to the users they serve.

