JEEAR, Vol. 4 (1), 2025

RESEARCH ARTICLE

DOI: 10.34002/jeear.v4i1.126

Development of an Efficient Schoolchildren Drop-Off and Pick-Up System in the Philippines: Enhancing Safety and Accessibility

Sanly Chris S. Alagos, Cid Jericho C. Turija, Dianna Faith D. Ramoran, Cristina P. Dadula, and Ryan G. Banal*

Electrical and Electronics Engineering Department, College of Engineering, Mindanao State University – General Santos, Fatima, General Santos City 9500, Philippines

*Corresponding Author: ryan.banal@msugensan.edu.ph

Received: January 15, 2025 | Revised: May 6, 2025 | Accepted: July 29, 2025 | Published: August 1, 2025

Abstract

Parents' concerns over traffic safety, congestion, limited parking, crime and the lack of efficient transport systems in developing countries have necessitated the use of private or small transport vehicles to drop-off and pick-up their children from school. While schools provide parking and designated drop-off and pick-up points for such vehicles, their increasing numbers have created a chaotic environment in school vicinities especially during peak hours. These situations exacerbate safety risks and congestion issues, causing frustration for schoolchildren, parents, and school administrators. To address this lack of systematic approach for drop-off and pick-up in schools, an efficient drop-off and pick-up system for schoolchildren was developed. The key components of the integrated management system include radio frequency identification (RFID) technology, local area network (LAN), database management, and a user interface. The development of such system represents a forward-thinking approach to managing school logistics. By leveraging technology to enhance safety, security, efficiency, and communication, this integrated system contributes to a more organized and secure environment, ensuring a smoother experience for children and other stakeholders involved.

Keywords: *congestion, parking, RFID, safety, schoolchildren*

The 2030 Agenda for Sustainable Development established by United Nations (UN) members in 2016, sets out 17 goals and 169 targets to eradicate poverty and realize a sustainable future by 2030 [1]. These Sustainable Development Goals (SDGs) tackle various global issues and challenges, including poverty, education, economic growth, sustainable cities, and climate change. Achieving these goals requires all nations to actively implement the global agenda. Specifically, SDG 4 focuses on providing inclusive and equitable quality education and promoting lifelong learning opportunities for all, while SDG 9 highlights the importance of information and communication technology (ICT) as a key driver in connecting technology with education towards implementation of all the SDGs [2-5].

As urbanization continues to rise, cities and communities become increasingly complex, putting pressure on existing infrastructure and systems, consequently impacting their abilities to meet set goals [6]. In response, United Nation Children's Fund (UNICEF) and UN-Habitat launched the Child-Friendly Cities Initiative (CFCI) in 1996, focusing on five key objectives, with safety as the top priority. These objectives aim to ensure that children grow up in safe environments, are treated equally, can freely express their opinions, have access to essential services, and enjoy family time and play [7]. In developing countries, efforts are mainly focused on expanding infrastructure, improving the environment, and enhancing social services [8]. However, due to concerns over crime and traffic safety, many parents rely on private vehicles or small transport vehicles, such as motorcycles or motorized tricycles, to drop-off and pick-up their children from school [9, 10]. Additionally, the lack of child-friendly mobility solutions in the Philippines, such as school transportation systems (e.g., bus services), forces

Filipino school children to use private or small public transport vehicles. Moreover, parents prioritize their children's safety during drop-off and pick-up, often opting for direct supervision to minimize potential risks. School administrators, in turn, focus on establishing safe zones and implementing security measures to ensure a secure environment for all [11, 12]. As a result, schools provide parking and designated drop-off and pick-up points for these vehicles. However, the high numbers of vehicles during drop-off and pick-up times create a chaotic environment, increasing safety risks and causing frustration for both school children and commuters. Data indicates that from 2005 to 2011, pedestrian accidents in Metro Manila rose by 21%, from 4,179 to 5,064, with one in five victims being minors. In 2011, 112 incidents occurred near schools, and Commonwealth Avenue had the highest count with 214 cases. The section fronting Diliman Preparatory School alone recorded 13 cases from 2006 to 2011 [13]. This risk is compounded during peak hours when the large number of vehicles dropping off and picking up school children often creates chaotic conditions around schools. This leads to significant safety and traffic congestion issues, putting school children at risk, especially with the increasing incidence of road accidents during these times [14]. Moreover, despite the presence of traffic officers, traffic remains disorganized, making congestion around schools a persistent problem that requires better prediction and management strategies. Drivers' behavior further exacerbates the situation, increasing safety risks and frustration for both school children, guardians, and commuters. Local schools frequently face difficulties with uncoordinated transportation arrangements, particularly during dismissal, creating confusion for school children. The lack of structured vehicle flow and direct communication between guardians further complicates matters. Additionally, the proximity of multiple schools along busy roads worsens congestion, leading to delays and stress. Therefore, schoolchild-friendly mobility initiatives, including safe travel environments for school children and efficient pick-up and drop-off systems, are becoming a priority [15].

In recent years, radio frequency identification (RFID) technology has transitioned from relative obscurity to mainstream use due to its ability to communicate wirelessly over a distance without requiring a direct line of sight [16, 17]. This technology enables the storage, retrieval, and rewriting of large volumes of data on a small chip, which can then be transmitted via radio frequency or waves. Recent advancements in data reading and storage capabilities have made RFID systems more affordable and versatile, leading to widespread adoption across various commercial and industrial applications. These include search, identification, tracking, and communication with objects, individuals, or items. Common use cases encompass access control, retail sales, supply chain management, inventory and asset tracking, equipment and vehicle monitoring, customer service, loss prevention, logistics, and shipping [18, 19].

Technological innovations in device communication and local network connectivity have further revolutionized how devices interact and exchange information. These developments have enhanced speed, reliability, and scalability in environments like schools, homes, offices, and industrial facilities. Systems that combine RFID-based data storage with local networks for monitoring and managing diverse functionalities are often referred to as Networked RFID Systems or Local RFID-Based Monitoring Systems [20]. Additionally, RFID has become a critical component of the Internet of Things (IoT), serving as a key technology for identifying physical objects [21]. In the Philippines, IoT is emerging as a transformative technology with the potential to significantly impact the lives of Filipino youth [22]. To fully leverage its benefits, innovative applications must be built on robust foundational systems or platforms.

For instance, in parking systems, an automated solution using RFID scanning at entry gates has been developed [23]. This system integrates a central database accessible online through a Wamp server, allowing vehicle owners to check parking availability and enabling automatic vehicle authorization. The database also provides analytical tools to identify parking demand patterns and mitigate congestion. Another RFID-based parking management system utilizes RFID tags, readers, and antennas to streamline operations, offering faster check-in and check-out processes to reduce traffic congestion at parking lot gates [24]. Furthermore, a novel car parking framework has been proposed, integrating Wireless Sensor Networks (WSN) and RFID, moving away from traditional methods like digital cameras and image processing for license plate recognition [25]. This system offers advanced features such as guidance services, car retrieval assistance, illegal parking detection, and enhanced security. Users can also access parking spot availability via an Android app connected to a network of sensors managed by a central mote. RFID-enabled sensors embedded in gates track vehicle movement from entry to specific parking spots, improving operational efficiency. A prototype of an IoT-based E-parking system is proposed to address the real-time detection of improper parking and automatic collection of parking charges [26].

However, most existing car parking solutions are designed for long-term use and do not cater to short-term scenarios like school drop-offs and pick-ups. While some systems utilize RFID for vehicle access, they often lack integration with child monitoring features, limiting their effectiveness in ensuring schoolchild safety. Additionally, because these services are open to all users without requiring pre-registration, they typically lack personalized tracking and robust security protocols. Existing systems also fall short in automation and real-time data processing, as they are not fully integrated. This leads to inefficiencies in data management, delayed responses, and potential safety lapses. To address this gap, this paper introduces the development of an RFID-based monitoring system tailored to the school environment. This system integrates RFID technology, a local area network (LAN), database management, and a user-friendly interface specifically designed for school environments. To the best of our knowledge, this is the first documented study focused on improving the drop-off and pick-up process for schoolchildren in the Philippines, where current methods typically involve manual identification, verbal verification by school guards or staff, and unregulated vehicle queues—often leading to traffic congestion, long wait times, and security vulnerabilities.

This study proposes a system designed to streamline the traditionally inefficient and disorderly processes associated with drop-off and pick-up by reducing pick-up and drop-off times, eliminating manual data logging, improving traffic flow efficiency, and strengthening safety protocols, such as increasing system accuracy in identifying authorized guardians and minimizing security incidents related to unauthorized retrieval. The outcomes collectively contribute to enhanced safety, security, and convenience through the use of technology. By fostering a more secure and organized school environment, the system aligns with SDG 9 by promoting investment in ICT that improves infrastructure, alleviates traffic congestion, and reduces safety risks to schoolchildren. In parallel, it supports SDG 4 by contributing to better educational outcomes through reduced tardiness and absenteeism, facilitated by real-time monitoring and optimized transport scheduling.

Materials and Methods

Development of Hardware and Software Interface for the Proposed RFID-based Management System

Figure 1 illustrates the typical situation during the drop-off and pick-up of schoolchildren, which serves as the basis for developing an RFID-based management system to improve these processes on school grounds. During drop-off, the process begins with a vehicle entering the school premises through the gate, proceeding to the designated parking area. Schoolchildren then alight from the vehicle and make their way to the school entrance, either on their own or with the assistance of a guardian or school staff. The vehicle subsequently exits through the designated gate. A comparable yet reversed process unfolds during the pick-up period. After class dismissal,

Figure 1. Diagram of the school parking area during the pick-up and drop-off of schoolchildren using private vehicles.

schoolchildren wait at the designated (waiting) area until their guardians arrive. Once the guardian's vehicle enters the parking area, the guardian either proceeds directly to the receiving area to retrieve the child or waits inside the vehicle before doing so. Then they walk together to the vehicle, which exits through the designated gate.

However, school drop-off and pick-up periods are frequently characterized by operational and safety challenges, including congested temporary parking areas, double-parking, blocked driveways, reduced visibility, and risks of vehicle theft or child abduction. These conditions often lead to delays caused by entry-point congestion, prolonged vehicle stoppages, uncoordinated procedures, inadequate preparedness of students, and non-adherence to established protocols. During pick-up, further delays arise due to inconsistent arrival times of guardians, difficulty in locating students, lack of a synchronized release process, congestion in designated zones, time-intensive security and identification checks, multiple pick-up locations, unsupervised waiting areas, and ineffective communication or alert systems. These issues that recur on a daily basis underscore the lack of integrated technological systems that can provide real-time notifications and facilitate smoother coordination within the school environment. Consequently, such disorganized environments increase the risks of accidents, hinder traffic flow, and pose significant safety concerns, particularly for schoolchildren navigating through unpredictable vehicle movements.

In a comparable school setting, data from our observational studies revealed that the average time required for schoolchild pick-up is 11.77 minutes per vehicle when delays, such as schoolchildren not promptly reaching the vehicle, are factored in. Without such delays, the process averages around 4.83 minutes.

The management system uses RFID as the communication device to acquire data from the vehicles entering and leaving the school premises. Among various communication devices, RFID is the most suitable, especially where low power consumption and simple identification tasks are critical [27-30]. The data acquired from the RFID is processed by the microcontroller according to the desired result. To implement the system, the materials and equipment needed are the NodeMCU V3 ESP8266 microcontroller, MFRC522 RFID reader, RFID cards, 5 mm light-emitting diodes (LEDs), and a power source. The choice of microcontroller and hardware components allows it to communicate with other devices, creating an embedded system for efficient data transfer and display purposes of the proposed integrated management systems. The NodeMCU V3 ESP8266 microcontroller was chosen due to its integrated Wi-Fi capability and cost-efficiency, making it more suitable for scalable, real-time data communication in school settings compared to the Arduino Uno, which requires additional connectivity modules. For RFID reading, the MFRC522 module was selected for its low cost, reliability, and compatibility, offering effective short-range scanning ideal for use at school gates. Although more advanced alternatives like the PN532 NFC module are available, the MFRC522 presents a more practical option for large-scale implementation. Combined, these components offer a cost-effective and scalable solution for accurate student tracking and streamlined data management. The RFID reader was made using the NodeMCU V3 ESP8266 microcontroller, MFRC522 RFID, and a power source.

In functionalities, the NodeMCU V3 ESP8266 microcontroller is used for connecting and controlling these devices. The MFRC522 RFID reader is used for reading RFID tags, while the RFID cards are used for vehicle identification. When the reader reads the RFID cards, a serial code is sent to the database, and when it matches the data, the corresponding data is recalled and an action is executed. Moreover, the 5 mm LEDs are used for visual indicators in the system. To establish a connection between the microcontroller and the reader, the hardware is interfaced by connecting the NodeMCU V3 ESP8266 digital pins to the corresponding pins of the MFRC522 RFID reader for code uploaded. This setup enables serial communication from the RFID reader to the NodeMCU V3 ESP8266. For the software interfacing, a resilient and user-centric application was created to employ data processing and real-time interactions by utilizing JavaScript, HTML, PHP, and SQL. Software development for the system followed the Agile methodology, enabling iterative planning, frequent stakeholder input, and continuous enhancement throughout the development lifecycle. The NodeMCU V3 ESP8266 functions as the system's central control unit, transmitting data to remote servers over a local area network. The RC522 RFID reader communicates with the microcontroller via the Serial Peripheral Interface (SPI) to read data from RFID tags. As a core component of the RFID architecture, the reader facilitates object identification and tracking by retrieving the unique information embedded in each tag. For database management, MySQL and phpMyAdmin were utilized to establish a structured and accessible online data framework. A web-based user interface, developed using JavaScript and HTML, displays schoolchild information and links each registered vehicle to a unique RFID card containing details such as the RFID serial number, name, gender, email address, and mobile number. Throughout the Agile development cycle, features were continuously tested and refined through iterative sprints to ensure the system met functional requirements and performed reliably in real-world conditions.

Figure 2 illustrates the registration form interface, where an authorized school official inputs essential information about schoolchildren and their guardians, including the RFID serial number, name, contact details, and vehicle plate number. These records are securely stored in an online database, protected through encryption protocols, role-based access controls, and compliance with the Philippines' Data Privacy Act. To safeguard sensitive information, access is restricted to authorized personnel, and only necessary data is displayed during verification process. Prior to data collection, informed consent will be obtained from parents or guardians. For monitoring and analysis, schoolchild data is anonymized to preserve privacy. Each RFID scan allows school personnel to verify and track pick-ups in real time, while maintaining data confidentiality and integrity.

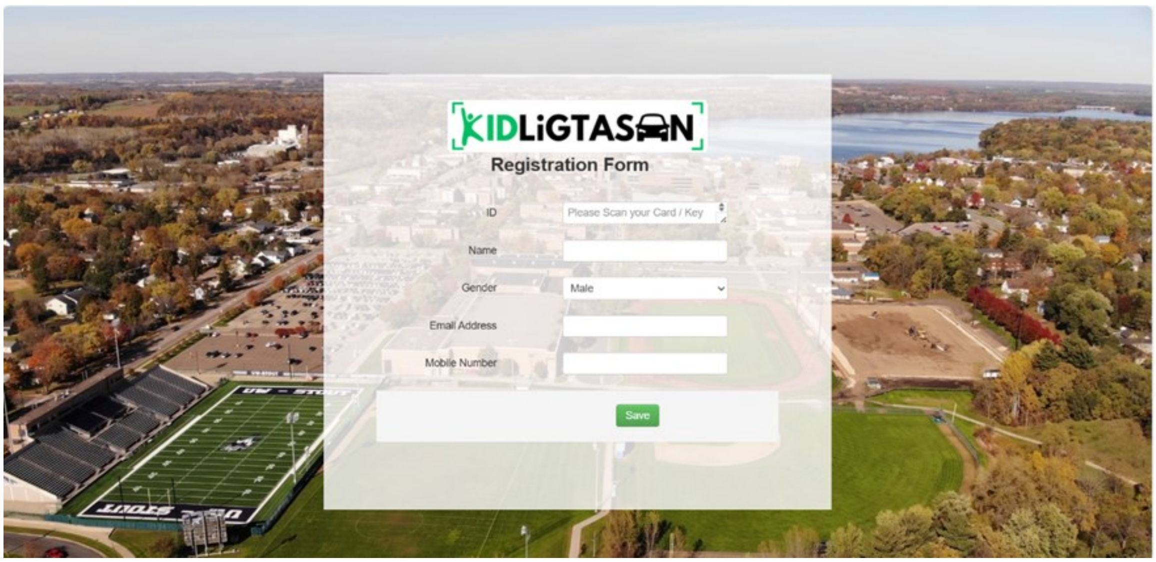

Figure 2. Registration Interface of the developed Web-based System

In Figure 3, the flowchart of the proposed RFID-based management system is shown, illustrating the integrated flowchart of the RFID reader prototype and data transmission process for vehicles entering educational institutions. The process begins at the gate entrance (**A**), where the RFID scanner reads the vehicle's RFID card, initiating both visual and audio feedback. The system then verifies the card against a centralized database. If authentication is successful and a parking spot is available, access to the designated parking area is granted. Subsequently, the schoolchild's name and relevant information are displayed on a screen at the waiting area (**B**). The schoolchild may then proceed to the pick-up point, either independently or accompanied by a school staff member. Upon vehicle exit (**C**), the RFID card is scanned again to update the database with the current parking status and record the pick-up time, accompanied by corresponding visual and audio notifications. This workflow forms the operational framework for the deployment of the proposed RFID-based monitoring system within a school setting.

Proposed RFID-based Management System for Managing Drop-off and Pick-up of Schoolchildren

In Figure 4, the proposed integrated management systems designed to facilitate the drop -off and pick-up of schoolchildren is presented. The system architecture is structured around the four layers of IoT framework: scanning, middleware, storage, and application levels, yet operates without internet-based interoperability with external devices or systems. At the scanning level, the RFID readers positioned at both entrance and exit gates detect and read RFID cards. The middleware layer, implemented through a LAN, enables communication among the RFID readers, the online database, and the visual display units. Data captured by the RFID readers is transmitted via the middleware to the online database, where it is processed to authenticate access and trigger

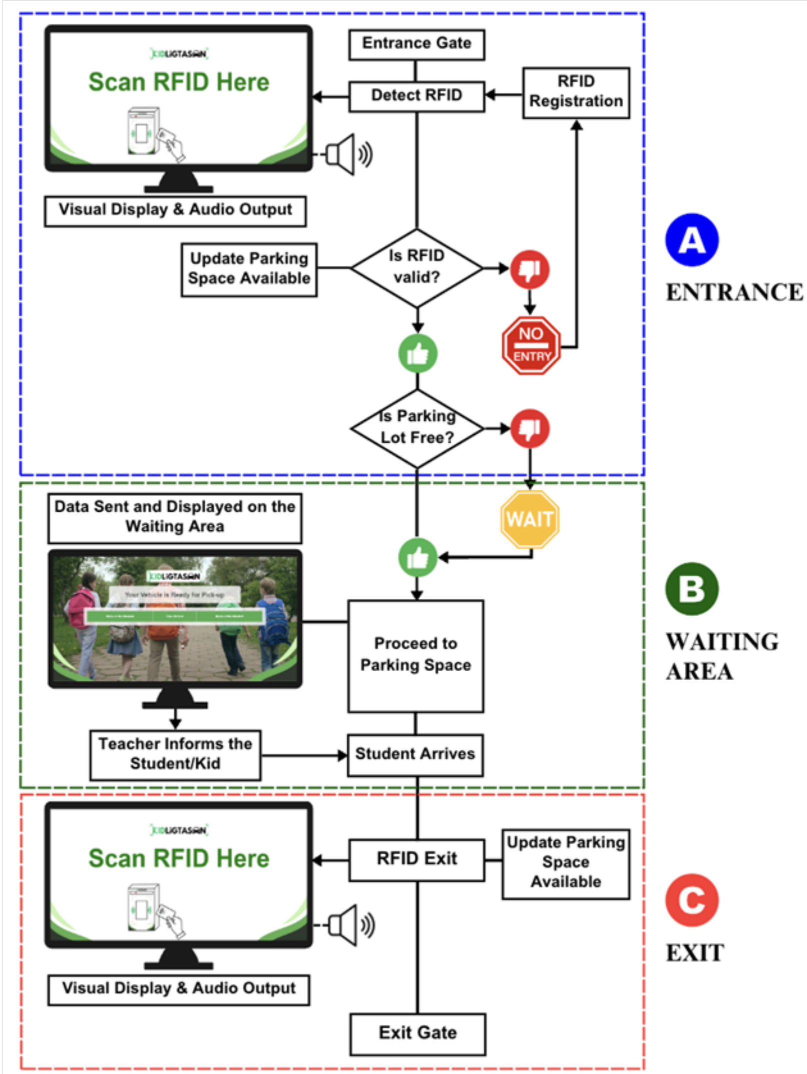

Figure 3. Flowchart of the Proposed RFID-based Management System for the Drop-off and Pick-up Process of Schoolchildren

corresponding system operations based on the data received.

The third level, referred to as the storage level, is responsible for housing all system data, which is maintained in an online cloud-based database. This serves as the main database where the data collected from the RFID reader is stored, analyzed, and matched. A free online database platform, MySQL, is used to create the database. It is then integrated with both the website and the RFID reader through a local network connection.

At the application or display level, system actions based on the data collected by the RFID reader and verified by the online database are executed through visual and audio output. The visual display shows information from scanned RFID cards at entry and exit points, including the schoolchild's name in the waiting area to indicate that a vehicle is ready for drop-off or pick-up. Additionally, the displays can show the date and time of arrival and departure, as well as the number of available parking spaces within the school grounds.

This study introduces a structured evaluation framework to assess the performance of the proposed RFID-based monitoring system for school transport management. The framework focuses on key performance indicators such as system response time, including both registration and server processing durations, to evaluate real-time operational efficiency. It also examines the reliability of the RFID prototype by analyzing detection accuracy at varying distances, specifically between 1.27 centimeters (cm) and 6.35 cm. Furthermore, the framework evaluates system performance under different operational

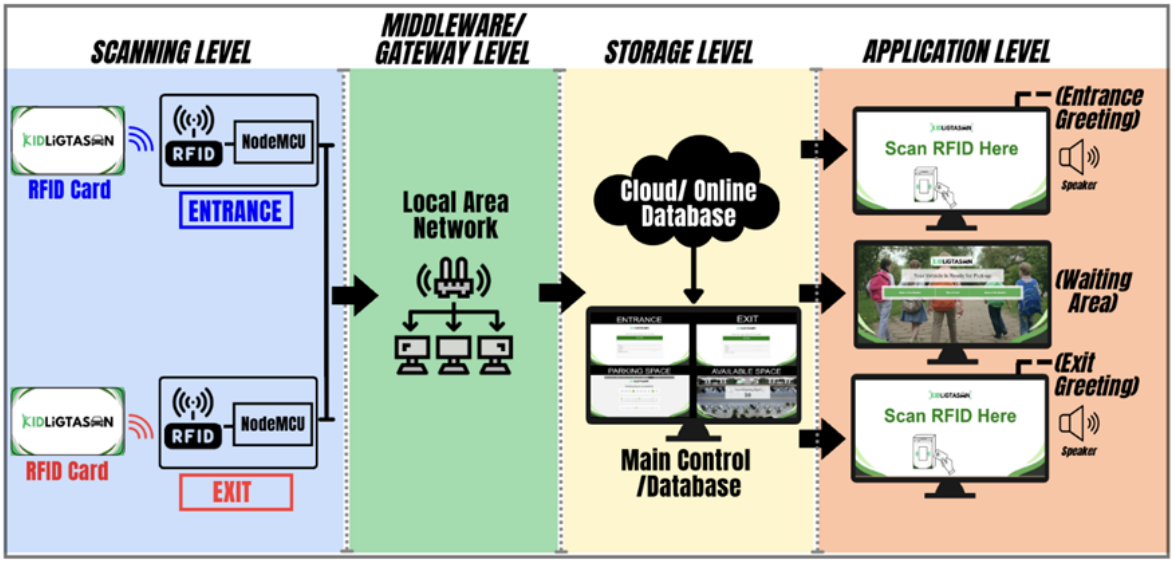

Figure 4. Framework of the Proposed RFID-based Management System for the Pick-up and Drop-off of Schoolchildren

scenarios, such as the presence or absence of schoolchild delays, and benchmarks these results against conventional school transport practices.

Results and Discussion

Software Interface and User Interaction Flow

Figure 5 presents the developed web-based interface that serves as the software component of the system, facilitating user interaction and system oversight. The interface comprises eight dedicated pages designed to ensure intuitive navigation and efficient monitoring: (1) RFID Registration Data, (2) RFID User Data, (3) RFID Scanning Data, (4) Schoolchildren's Name Display, (5) Logs Display, (6) Total Available Parking Space Display, (7) Available Parking Space Display, and (8) Control Room Display. User interaction begins with the RFID registration process, where essential user information, such as ID, name, gender, email address, and mobile number, is collected and stored. The RFID User Data page allows users to manage these records by viewing, editing, or deleting entries, as well as monitoring corresponding time-in and time-out logs. Upon RFID tag scanning, the system cross-verifies the tag against the registered database. If the tag is recognized, the associated user details are displayed; otherwise, an error notification appears. During schoolchild pick-up times, the system displays the names of schoolchildren whose transportation has arrived, thereby streamlining the coordination and security of the handover process. The Logs Display page provides access to detailed entry and exit logs, which can be exported in Excel format for reporting or analytical use. Parking management is enabled through dynamic displays showing both the total number of available slots and the real-time status of individual parking spaces, with visual aids such as color indicators improving interpretability. The Control Room Display page consolidates real-time monitoring of entry/exit points and parking utilization, offering a centralized platform for managing campus traffic and ensuring safety and operational coordination.

Performance of RFID-based Management System for Drop-off and Pick-up of Schoolchildren

Figure 6 illustrates the expected improvement in the flow of vehicles in and out of the parking area during drop-off and pick-up of schoolchildren. As seen in the figure, the scanning level is located at the entrance and exit points (marked by **A** and **C**), while the visual displays are in the waiting area (**B**), the control room, and at the exit (**A**) and entrance (**C**) which is defined in the application level of the framework. Together with the RFID reader and the LAN, the transfer of data between the cloud and the visual displays is made seamless and efficient. The devices operate on electricity and are equipped with a backup power supply to maintain functionality in the event of power outage.

Presented in Figure 7 is the flowchart of the RFID-based management system, illustrating the corresponding functions at each level of the framework. The process begins at the entrance, where RFID cards are scanned by the entrance RFID reader to authenticate the entry of the

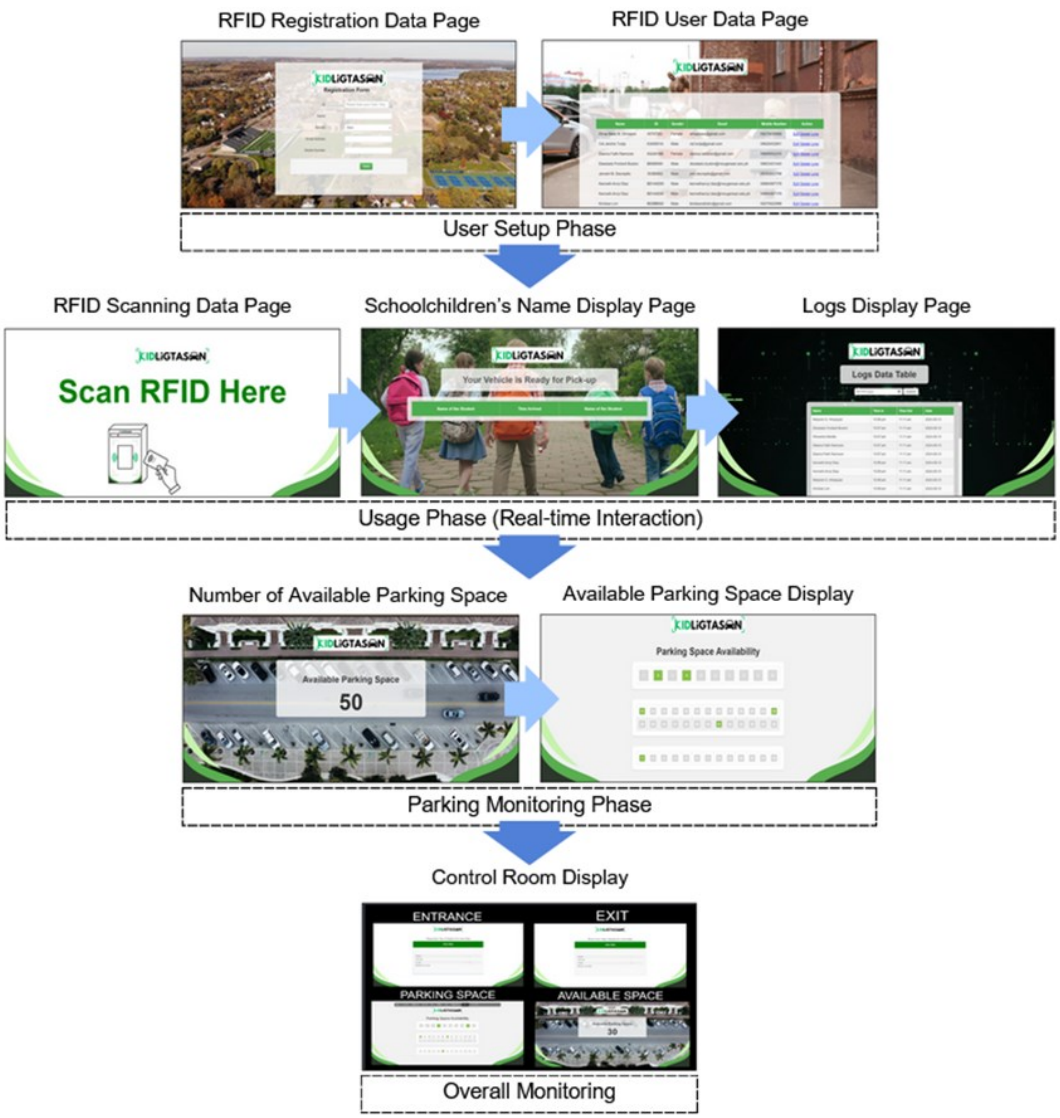

Figure 5. Web-Based Software Interface and User Interaction Flow of the Proposed RFID-based Management System

vehicle. The NodeMCU V3 ESP8266 transmits data from the RFID reader to the other components via the LAN, enabling real-time display. Upon exit, the RFID reader scans the RFID card once again to record the time and remove the corresponding schoolchild's name from the waiting list database, indicating that the schoolchild has left the school grounds. Daily, the collected data is archived in the cloud, with filenames based on the date to facilitate easy retrieval and export. Accessing or modifying data in online database requires a security password, a feature implemented during the development to ensure data privacy and system security.

To assess the performance of the developed system in terms of functionality, operational feasibility, implementation challenges, hardware and software behavior, and process flow, a small-scale pilot test was conducted at a location within the university premises. This site was selected in place of the original study location due to strict school protocols that prohibited the collection of data involving actual schoolchildren. Nevertheless, efforts were made to ensure that participating students realistically mimicked the movements and behaviors of schoolchildren. A motorcycle was used as the test vehicle, with university students acting in the role of schoolchildren. A 25×25 square meter area was designated for the setup, with display units installed at the entry and exit points, as well as in the waiting area. The vehicle parking zone was centrally positioned within the designated space. A local Wi-Fi LAN connected the RFID reader to the

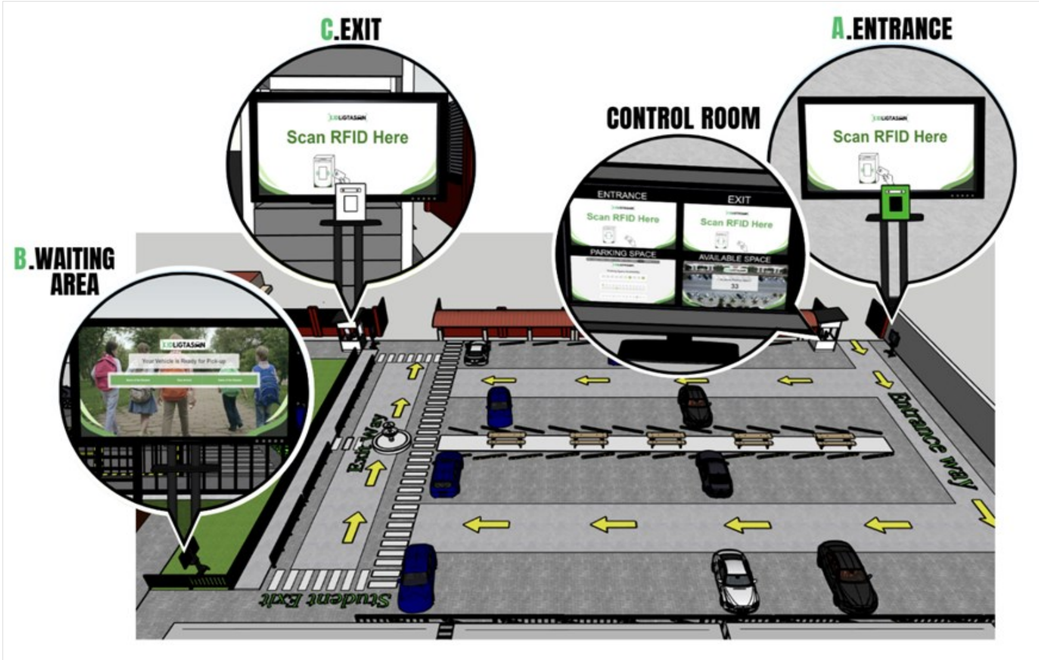

Figure 6. Vehicle Flow Management During Drop-off and Pick-up of Schoolchildren.

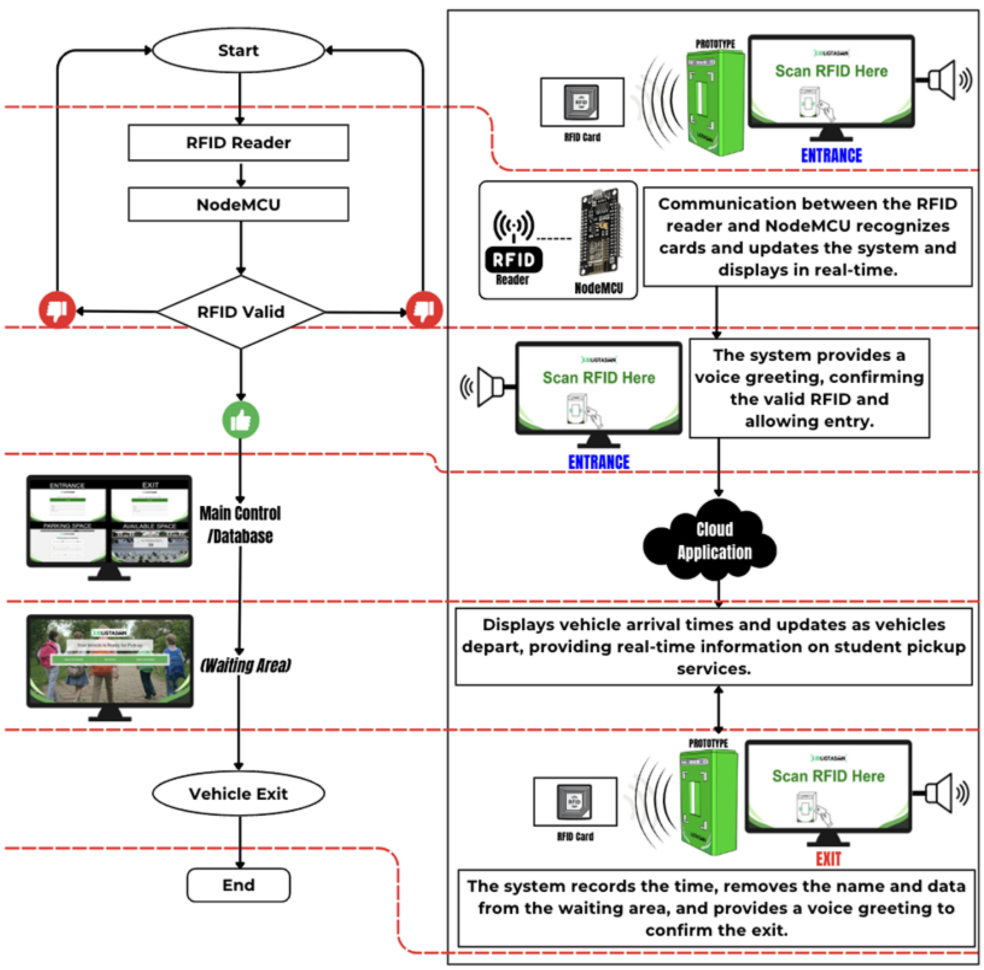

Figure 7. Flowchart of RFID Data Processing in the RFID-based Management System of Drop-off and Pick-up of Schoolchildren

database computer, enabling seamless data transmission. The results of the pick-up process are presented in Table 1.

An independent samples t-test was conducted to compare schoolchild pick-up times under two conditions: with and without delay. The results in Table 2 showed that pick-up times were significantly longer when delays were present (**M = 165.9**, **SD = 127.8**) compared to when no delays occurred (**M = 34.1**, **SD = 7.2**); **t(58) = 5.6, p < 0.0001**. This suggests that traffic or logistical delays contribute meaningfully to longer pick-up durations. The results also indicate a significant improvement compared to average durations observed in actual school settings, which typically range from 706 seconds (11.77 minutes) with delays to 290 seconds (4.83 minutes) without. However, caution is advised when interpreting these comparisons, as the testing conditions differed from real-world school environments.

Table 1. Pilot test data obtained during the pick-up process using the developed RFID-based management system for the drop-off and pick-up of schoolchildren

Vehicle No.	**Pick-up Time Duration (seconds)**	
	With Student Delay	Without Student Delay
1	120	25
2	58	28
3	60	40
4	540	37
5	480	32
6	420	26
7	59	26
8	240	37
9	240	26
10	240	28
11	240	49
12	240	45
13	120	33
14	120	28
15	120	40
16	60	39
17	60	35
18	60	29
19	60	46
20	180	28
21	180	29
22	240	36
23	120	45
24	180	37
25	60	47
26	60	28
27	60	36
28	60	30
29	120	27
30	180	29

The system was evaluated using key performance indicators such as registration and server response times, RFID reading accuracy at varying distances, and operational performance under conditions with and without schoolchild delays. These metrics demonstrated gains in operational efficiency, schoolchild safety, and traffic flow, emphasizing the system's contribution to developing smart and resilient school infrastructure. However, limitations were observed, including occasional delays in RFID tag reading, network latency, and minor inefficiencies. Notably, RFID reliability declined beyond a distance of 5.08 cm, limiting flexibility in tag placement. Identified risks included tag spoofing, network outages, and hardware failures. To address these, the system integrates encryption and authentication protocols, backup connectivity solutions, and redundant hardware components to maintain functionality during disruptions. While these safeguards bolster system reliability, user acceptability—particularly among parents and schoolchildren—could not be assessed due to the constrained testing scope and location. Nonetheless, the system showed strong potential to improve process efficiency under optimal conditions.

The integration of RFID technology, a LAN, database administration, and a user-friendly interface works cohesively to enhance security in the drop-off and pick-up process by accurately identifying authorized individuals and maintaining real-time records. Simultaneously, this coordinated system helps reduce traffic congestion by streamlining schoolchild handovers and minimizing delays at school entry and exit points. To further enhance the capabilities of the developed RFID-based management system, the integration of surveillance cameras at entry and exit points is recommended. This addition would strengthen security by enabling real-time visual monitoring of vehicles and schoolchildren, as well as archiving recorded footage for future reference. The incorporation of facial recognition technology could also streamline the identification process, allowing for faster and more accurate verification of schoolchild identities during drop-off and pick-up periods. Moreover, the development of a dedicated mobile application could offer parents real-time updates on their children's status, thereby improving communication and reinforcing safety.

Table 2. Comparison of Schoolchild Pick-up Times With and Without Delay (N = 60)

Condition	Mean (M)	Standard Deviation (DV)	t-value	df	p-value
Without Delay	165.9	127.8			
With Delay	34.1	7.2	5.6	58	<0.0001

Transitioning the system into an IoT framework, through the integration of interconnected physical devices, vehicles, and sensors equipped with software and network connectivity, could further elevate the system's functionality in the context of smart mobility for schoolchildren. To support this enhanced framework, the establishment of a robust infrastructure is essential. This includes reliable internet access, an uninterrupted power supply, secure installation of all hardware components, and a system for continuous maintenance and updates to accommodate future security and technological developments.

Conclusion

This study introduced a management system for the drop-off and pick-up of schoolchildren, leveraging RFID technology. Although RFID-based systems have been explored in similar contexts, this system distinguishes itself by its integration of RFID technology, a LAN, database management, and a user-friendly interface specifically designed for school environments. It features an identification mechanism that combines RFID tags and readers to improve both security and operational convenience. Additionally, a centralized database was developed to efficiently store and manage schoolchildren's personal information, ensuring streamlined access and data integrity tailored to the needs of local schools. Results from pilot testing showed that the prototype significantly outperformed the traditional system in time efficiency. Vehicles in the prototype system took an average of 166 second (2.77 minutes) with schoolchild delays and 34 seconds (0.51 minutes) without delays. In comparison, the traditional system took 706 seconds (11.77 minutes) with delays and 290 seconds (4.83 minutes) without, demonstrating the prototype's superior efficiency in streamlining the process. The RFID-based system was realized as a cost-efficient device tailored for implementation in educational institutions. This solution addresses congestion and security concerns in schools by enabling rapid and efficient data transfer through a centralized database, utilizing cloud storage for seamless data access and retrieval. However, implementing an RFID-based Management System for the drop-off and pick-up of schoolchildren in the Philippines presents several practical challenges, including financial, operational, and technical factors. Upfront expenses cover the cost of RFID tags per schoolchild, RFID readers, and software development. Additional spending is required for wiring and installation at each location. Ongoing costs involve cloud hosting, maintenance, and technical support. The system also demands regular tag replacement, hardware servicing, and software updates, along with continuous technical support for staff training, troubleshooting, and onboarding users. External factors such as frequent power outages, unreliable internet, limited school budgets, and varying levels of digital literacy among parents and staff can also impede successful deployment, particularly in rural and public school settings.

Although the developed system exhibited certain limitations, addressing the hardware components would ensure overall reliability and robustness. To improve effectiveness and sustainability, a phased rollout with pilot testing is advised. For future enhancements of the RFID-based system, it is recommended to adopt Ultra High Frequency (UHF) RFID technology to extend the reading range and improve system responsiveness. The integration of infrared or ultrasonic sensors can enhance the accuracy of parking space detection. Additionally, leveraging artificial intelligence (AI) can optimize parking management by analyzing usage patterns and forecasting peak periods. To improve system flexibility, alternative access options such as guest passes or RFID-enabled visitor modes may be implemented. The development of a mobile application for parking reservations and real-time notifications would significantly enhance user convenience. Integration with existing school management systems can further improve coordination, data sharing, and security. Incorporating closed-circuit television (CCTV) surveillance and secure access control mechanisms will strengthen safety protocols. The installation of automated boom barriers or access-control gates at entry and exit points can also be considered to streamline vehicle flow. Continuous updates to the system's web interface are essential to maintain usability and ensure a smooth user experience. Moreover, the system is designed to support seamless integration with IoT technologies, enabling scalable operations and facilitating future technological upgrades.

Author's Contribution

R.G.B. was responsible for advising and supervising the entire process, including data collection, implementation of the design, testing, and data analysis. C.P.D. provided guidance and oversight throughout the study. S.C.S.A., D.F.D.R., and C.J.C.T. were involved in carrying out the design implementation, conducting tests, and gathering data.

Acknowledgment

The authors would like to acknowledge the valuable contribution of The Quantum Academy, Inc. for the conduct of this study.

References

[1] United Nations. (2015). *The 17 Sustainable Development Goals*. https://sdgs.un.org/goals

[2] Ferguson, T., Hill, S., Iliško, D., & Roofe, C. (2019). *SDG4 - Quality education: Inclusivity, equity and lifelong learning for all.* Emerald Publishing Limited.

[3] McKay, V. (2018). Literacy, lifelong learning and sustainable development. *Australian Journal of Adult Learning*, *58*(3), 390–425.

[4] Saini, M., Sengupta, E., Singh, M., Singh, H., & Singh, J. (2022). Sustainable Development Goal for Quality Education (SDG 4): A study on SDG 4 to extract the pattern of association among the indicators of SDG 4 employing a genetic algorithm. *Education and Information Technologies*, *28.* https://doi.org/10.1007/s10639-022-11265-4

[5] Blazhevska, V. (2017). Sustainable Development Goal 9: Investing in ICT access and quality education to promote lasting peace. *United Nations Sustainable Development.* Retrieved from https://www.un.org/sustainabledevelopment/blog/2017/06/sustainable-development-goal-9-investing-in-ict-access-and-quality-education-to-promote-lasting-peace/

[6] Ritchie, H., Roser, M., & Samborska, V. (2018). Urbanization. *Our World in Data.* https://ourworldindata.org/urbanization

[7] Liao, Y., & Furuya, K. (2023). A bibliometric analysis of child-friendly cities: A cross-database analysis from 2000 to 2022. *Land*, *12*(10), 1919. https://doi.org/10.3390/land12101919

[8] Hedges, S., Borgerhoff Mulder, M., James, S., & Lawson, D. (2016). Sending children to school: rural livelihoods and parental investment in education in northern Tanzania. *Evolution and Human Behavior*, *37*(2), 142–151. https://doi.org/10.1016/j.evolhumbehav.2015.10.001

[9] Nasrudin, N., & Nor, Abd. R. Md. (2013). Travelling to school: Transportation selection by parents and awareness towards sustainable transportation. *Procedia Environmental Sciences*, *17*, 392–400. https://doi.org/10.1016/j.proenv.2013.02.052

[10] Rivera, Y. K. & Castro, J. T. (2022). Determinants for modal shift of school children from private vehicles to public transport: a case study in Metro Manila, Philippines. *Proceedings of the 28th Annual Conference of the Transportation Science Society of the Philippines.* https://ncts.upd.edu.ph/tssp/wp-content/uploads/2023/01/TSSP2022_12.pdf

[11] Sattanon, K. & Upala, P. (2018). Evaluation of risk factor for children during drop-off and pick-up time around primary school in Thailand. *The Open Transportation Journal, 12,* 301–318. http://dx.doi.org/10.2174/1874447801812010301

[12] Hiep, D. V., Huy, V. V., Kato, T., Kojima, A., & Kubota, H. (2020). The effects of picking up primary school pupils on surrounding street's traffic: A case study in Hanoi. *The Open Transportation Journal*, *14*, 237–250. http://dx.doi.org/10.2174/1874447802014010237

[13] Barrientos-Vallarta, B. (2012, June 20). Pedestrian accidents in school zones: 1 in 5 victims is a child. *GMA News Online*. https://www.gmanetwork.com/news/topstories/specialreports/262514/pedestrian-accidents-in-school-zones-1-in-5-victims-is-a-child/story/

[14] Balita, C. (2023). Philippines: Number of kidnapping cases 2022. *Statista*. https://www.statista.com/statistics/1170777/philippines-number-of-kidnapping-cases

[15] Gu, T., Xu, W., Liang, H., He, Q., and Zheng, N. (2024). School bus transport service strategies' policy-making mechanism – An evolutionary game approach. *Transportation Research Part A: Policy and Practice*, *182*, 104014. https://doi.org/10.1016/j.tra.2024.104014

[16] Want, R. (2006). An introduction to RFID technology. *IEEE Pervasive Computing*, *5*(1), 25–33. https://doi.org/10.1109/MPRV.2006.2

[17] Roussos, G., & Kostakos, V. (2009). RFID in pervasive computing: State-of-the-art and outlook. *Pervasive and Mobile Computing*,

5(1), 110–131. https://doi.org/10.1016/j.pmcj.2008.11.004

[18] Zhu, X., Mukhopadhyay, S. K., & Kurata, H. (2012). A review of RFID technology and its managerial applications in different industries. *Journal of Engineering and Technology Management*, *29*(1), 152–167. https://doi.org/10.1016/j.jengtecman.2011.09.011

[19] Chao, C.-C., Yang, J.-M., & Jen, W.-Y. (2007). Determining technology trends and forecasts of RFID by a historical review and bibliometric analysis from 1991 to 2005. *Technovation*, *27*(5), 268–279. https://doi.org/10.1016/j.technovation.2006.09.003

[20] Abd Wahab, M. H., Abdul, H., Tukiran, Z., Sudin, N., Ab. Jalil, M. H., & Johari, A. (2011). RFID-based equipment monitoring system. In C. Turcu (Ed.), *Designing and Deploying RFID Applications* (pp. 175–188). IntechOpen. https://doi.org/10.5772/18776

[21] Tan, C. C., & Wu, J. (2013). Security in RFID networks and communications. In *Wireless Network Security* (pp. 247–267). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-36511-9_10

[22] Kato, G. A., Yamongan, J. S., Manao, J. M. N., Arcega, R. A. A., Espino, R. L. E., Capili, R. D. S., & Magsumbol, J. A. V. (2022). Emerging technologies in the Philippines: Internet of Things (IoT). In S. R. R. S. Prabhakar, A. K. R. S. Babu, & A. K. S. Rehani (Eds.), *Intelligent computing & optimization* (pp. 300–308). Springer. https://doi.org/10.1007/978-3-031-19958-5_28

[23] Kannadasan, R., Krishnamoorthy, A., Prabakaran, N., Naresh, K., Vijayarajan, V., & Sivashanmugam, G. (2016). RFID-based Automatic Parking System. *Australian Journal of Basic and Applied Sciences*, *10*(2), 186–191. Retrieved from https://www.ajbasweb.com/old/Ajbas_Special-1%20_2016.html

[24] Chatterjee, A., Manna, S., Rahaman, A., Sarkar, A. R., Ghosh, A., & Ansari, A. A. (2019). An automated RFID based car parking system. In *Proceedings of the 2019 International Conference on Opto-Electronics and Applied Optics (Optronix)* (pp. 1–3). IEEE. https://doi.org/10.1109/OPTRONIX.2019.8862411

[25] Karbab, E., Djenouri, D., Boulkaboul, S., & Bagula, A. (2015). Car park management with networked wireless sensors and active RFID. In *2015 IEEE International Conference on Electro/Information Technology (EIT)* (pp. 373–378). IEEE. https://doi.org/10.1109/EIT.2015.7293372

[26] Sadhukhan, P. (2017). An IoT-based e-parking system for smart cities. In *2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI)* (pp. 1062–1066). IEEE. https://doi.org/10.1109/ICACCI.2017.8125982

[27] Khanna, A., & Kaur, S. (2019). Evolution of Internet of Things (IoT) and its significant impact in the field of precision agriculture. *Computers and Electronics in Agriculture*, *157*, 218–231. https://doi.org/10.1016/j.compag. 2018.12.039

[28] Samala, H. D., Ogale, G. S., & Ogale, M. M. (2020). *Enemy at the gates: Safety and security in Philippine schools.* ResearchGate. https://www.researchgate.net/publication/341441128_Enemy_at_the_gates_Safety_and_Security_in_ Philippine_Schools

[29] Tuazon, A. C. (2023). Safety in our schools. *Inquirer.net*. Retrieved from https://opinion.inquirer.net/160589/safety-in-our-schools

[30] Rehman, M. U., Shah, M. A., Khan, M., & Ahmad, S. (2018). A VANET-based smart car parking system to minimize searching time, fuel consumption, and CO2 emission. *Proceedings of the 24th International Conference on Automation and Computing (ICAC)* (pp. 1–6). IEEE. https://doi.org/10.23919/IConAC.2018.8749028