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# Developing Vehicles Duty Payment and Tracking System for the Nigerian Custom Service

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## ABSTRACT

The manual system of custom duty payment in Nigeria is faced with many challenges including multiple registrations issued by various agencies of Government for a single vehicle, creating opportunities for fraud as officers cannot verify the authenticity of documents issued by other agencies. This study designed and implemented a prototype vehicles duty payment system for the Nigerian Custom service using the Structured Systems Analysis and Design Methodology (SSADM). The system integrated RFID card sensor, QR code reader and unique keypad to log in and access the system for verification and payment status. Results showed that upon deployment, the system synchronized very well with the Nigeria customs database thereby enabling effective enforcement of duty payment regulations. The interface supports efficient monitoring and management of vehicle duty payments which allows customs officers to perform thorough verifications, ensuring that the vehicles comply with customs regulations. By providing real-time access to these details, the system guarantees accuracy and reliability of the duty payment verification process, thereby preventing fraud and ensuring proper documentation before vehicles are cleared at the customs checkpoints. The secure, real-time data retrieval and comparison process further bolsters the system's effectiveness in maintaining compliance and preventing illegal activities. Therefore, by deploying this system for the Nigerian customs service will boost productivity, increase revenue and enhance efficiency of the custom services.

**Keywords:** Vehicle identification, duty payment, tracking, QR code, RFID card sensor, Nigerian Custom service

### CISDI Journal Reference Format

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Ladoja, K.T., Hamzat, Z.A. & Waziri, M. (2025): Developing Vehicles Duty Payment and Tracking System for the Nigerian Custom Service. *Computing, Information Systems, Development Informatics & Allied Research Journal*. Vol 16 No 3, Pp 1-22.  
Available online at [www.isteams.net/cisdijournal](http://www.isteams.net/cisdijournal). [dx.doi.org/10.22624/AIMS/CISDI/V16N3P1](https://doi.org/10.22624/AIMS/CISDI/V16N3P1)

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## 1. INTRODUCTION

Vehicle duty payments and registration in Nigeria began over 100 years ago, with records largely maintained manually. This manual system has hindered the efficiency of automotive services and operations by relevant agencies in recent years (Godswill, 2024; Adisa & Eludiora, 2021). Today, computers have proven to be highly effective tools for managing information across various economic sectors. The shift to computerized systems is crucial for improving vehicle duty payment and registration processes, as it addresses many issues associated with manual data processing (Sherifat et al., 2019).

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The world is undergoing a revolution in information and knowledge, fundamentally transforming human activities. Governments globally are rapidly adopting e-government to enhance services for businesses and citizens, foster economic and social development, and improve the efficiency and effectiveness of operations (Osang et al (2021). Computers play a crucial role in this transformation by solving complex problems and processing vast amounts of data rapidly. The emphasis on information and data processing has notably increased in various sectors, including motor vehicle duty payment and registration (Cascio & Montealegre, 2016).

The growth in computer technology development is increasing as long as more research is performed on a daily basis. Information technology improvement has gone versatile over the world on different applications in every country (Okeke & Ezenwegbu, 2018). Advancement in technology comes with the need for individuals and organizations to harness the power of information technology to make their duties easier (Ajodo, 2015). This ongoing initiative motivated the design and implementation of an integrated system to unify all payments and collections related to vehicle clearance and registration. Therefore, the objective of this study is to design and implementation of a Smart Vehicle Duty Payment Monitoring and Management System (SVDPMMS), an Android Application system capable of enhancing the effectiveness and efficiency of vehicle duty payment verification and registration in Nigeria. In this research, attention is given to how information technology can be harnessed to automate vehicle clearing and registration in Nigeria.

The device is designed to synchronize with a server to verify the payment of duties and excise. It captures data such as date, time, GPS coordinates, and the login details of the user handling the device. The device is synchronized to update records both from the device to the server and from the server to the device. The AVDPVIS is integrated with an RFID card sensors, a QR code reader, and a unique key (PIN) authentication system to verify the authenticity of vehicle duty payments within seconds by field officers. The verification process is entirely offline, eliminating fraud related to improper duty payments and reducing the cost and need for printing proof of payment, thereby accelerating the verification process. AVDPVIS will also be integrated into the existing Customs-centric Single Window Portal, such as NICIS II, which is part of the Single Window platform, enabling standardized information and document submission through a single-entry point for all import, export, and transit-related regulatory requirements.

## 2. LITERATURE REVIEW

Andutan & Ucat, (2022) conducted a study aimed at designing an easy-to-use vehicle tracking and monitoring system with route deviation detection and SOS capability. The system utilized Global System Monitoring - Short Message Service (GSM-SMS) technology to send notifications and location details when the vehicle deviated from its predetermined path. The study successfully developed a prototype that demonstrated the feasibility of implementing route deviation detection, emergency command, and current status command using Arduino, GPS, and GSM technologies within the Structured Systems Analysis and Design Method (SSADM) framework. Dilip et al. (2022) proposed an embedded system for vehicle tracking and positioning, employing GPS and GSM modules. The study emphasized the system's utility, particularly in accident scenarios occurring in remote locations or during nighttime. The system was also developed using the SSADM approach, reinforcing its practical application and effectiveness in critical situations.

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In the context of vehicle monitoring and human detection using the Internet of Things (IoT), numerous advancements have been made to enhance the safety and efficiency of transportation systems. Singh et al. (2021) developed a robotic vehicle system capable of detecting human movement through a Passive Infrared (PIR) sensor. This sensor, operating on a 5V DC power supply, captures thermal radiation emitted by the human body, triggering the robot's movement through an H bridge-controlled DC motor. The system also integrates a Bluetooth module for remote control and an ESP32 wireless camera for real-time visual feedback in disaster scenarios. Additionally, ultrasonic sensors detect obstacles, enabling the robot to navigate autonomously, while an Arduino Uno board manages the entire operation, ensuring user-friendly, economical, and efficient human detection and rescue operations.

Further innovations in vehicle monitoring are highlighted by Singh et al. (2022), who implemented a vehicle monitoring and accident detection system using IoT. This system utilizes Python 3.7 for face recognition to prevent unauthorized access, integrating GPS and GSM modules for theft detection and vehicle tracking. The system sends alerts to the vehicle owner and, if necessary, to nearby police stations with the intruder's image. Moreover, the system incorporates gas sensors to detect alcohol consumption by drivers and IR sensors to avoid collisions, enhancing overall vehicle safety. Sabri and Maizate (2021) proposed an IoT-based smart vehicle security and safety system aimed at reducing road fatalities. The system is designed not only to prevent accidents but also to implement post-crash measures. By addressing the root causes of crashes and integrating safety measures, the project seeks to significantly enhance road safety.

Dudhpachare (2022) designed a vehicle tracking system using GPS and GSM technology, one of the most common methods for real-time vehicle tracking. The system uses an Arduino Uno to control the GPS receiver and GSM module, sending location updates via SMS to the vehicle owner. The system also displays the vehicle's location on Google Maps, enabling continuous monitoring through a smartphone. Oluwashola and Ige (2022) developed a Vehicle Information System (VIS) for data mining and management, aimed at improving vehicle maintenance and usage management within organizations. The VIS, built using Visual Basic 6.0 and Microsoft Office Access 2010, was found to enhance fleet management by reducing vehicle downtime and improving overall efficiency.

Seyhun et al., 2021 explored a method for deriving traffic information using cameras installed at intersections to enhance road monitoring systems. The study employed Object-Oriented Analysis and Design (OOAD) and achieved a 99% vehicle detection performance with less than 20% errors in vehicle classification and lane-by-lane travel volume estimation. This automated system design proved effective in improving traffic monitoring. Akande et al., 2021 designed a vehicle detector and counter system using inductive loop technology, utilizing Structured Systems Analysis and Design Method (SSADM). Simulated and tested in Proteus virtual system modeling software, the design demonstrated potential for effective vehicle detection and counting at intersections to control traffic. Babalola & Olokun, 2021 developed a vehicle accident detection and messaging system using GSM and GPS modules, employing SSADM. The microcontroller-based design is noted for its flexibility and accuracy, ensuring reliable automated accident reporting. Vinodha et al., 2021 introduced a system that uses RFID modules to automate toll collection and vehicle identification at toll plazas. The system also addresses vehicle theft and hit-and-run cases by matching vehicle numbers with data stored in a cloud database, thus reducing traffic congestion. The study utilized SSADM and demonstrated the effectiveness of this automated system design.

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Tejashwini & Subodh, 2021 proposed a method for vehicle theft detection, tracking, and accident identification using the Internet of Things (IoT), employing OOADM. The system simplifies the detection and tracking of stolen vehicles, ensuring timely notifications to vehicle owners. Zhihui & Hai, 2021 developed an adaptive cruise control system based on distance detection, employing OOADM. The system provides audio and visual alarms if a vehicle's detected distance falls below the safety threshold, and effectively facilitates information exchange between the vehicle and the control center, enhancing road safety. Duraichi et al., 2021 implemented an automated smart license verification system for vehicles, using OOADM. The system ensures vehicle operation only after authentication of the registered owner, enhancing vehicle security. Mao et al., (2021) focused on improving identity authentication security for the Internet of Vehicles by leveraging Hyperledger Fabric's modular components. The OOADM-based study revealed that the proposed method effectively enhances security in vehicle identity authentication.

Oluwatobi et al. (2021) explore the design of a vehicle detector and counter system using inductive loop technology, aimed at improving traffic control at intersections. The system utilizes an inductive loop to detect vehicles through electromagnetic communication, which increases the loop's inductance as vehicles pass over it. An electronic detector section, incorporating a voltage comparator and Darlington transistor arrangement, processes the signals to count vehicles using two up-counters and an up/down counter. Simulation in Proteus software demonstrated the system's effectiveness in vehicle detection and counting, which could significantly enhance traffic management by determining the optimal intersection access based on vehicle volume.

Babalola and Olokun (2021) focus on the development of a microcontroller-based vehicle accident detection and reporting system, leveraging GSM and GPS technologies. The system detects severe accidents through signals from accelerometers and sends an alert with precise GPS coordinates to emergency services. Vibration and MEMS sensors detect crashes or rollovers, triggering the ARM controller to send SMS notifications. The system is designed for flexibility and accuracy, utilizing tested and configured GSM/GPS modules to monitor and report the vehicle's location in real-time. This system is crucial for providing timely medical intervention, potentially saving lives by minimizing the delay between an accident and the arrival of emergency responders.

Tejashwini and Panda (2021) present a low-cost IoT-based system for vehicle theft detection, tracking, and accident identification. The system utilizes a microcontroller to monitor vehicle status, displaying messages on an LCD and sending alerts via GSM. In the event of theft, the system notifies the owner, enabling remote control of the vehicle's ignition and real-time tracking of its location. The system also captures and sends the thief's photo to the owner, enhancing security. Designed for affordability and simplicity, this system allows easy detection and quick response to vehicle theft and accidents, making it accessible for a wide range of users.

Sabri et al. (2021) introduce an IoT-based system designed to prevent road accidents and respond effectively when they occur. The system integrates measures to detect and avoid potential crashes, as well as to manage post-crash scenarios. The design focuses on both functional and non-functional requirements, providing an innovative solution to the growing problem of road safety. Experimental results show that this model outperforms existing devices, offering improved sensitivity and response times, thereby enhancing vehicle security and reducing the risk of fatal accidents.

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Duraichi et al. (2021) present an automobile authentication and tracking system employing deep learning techniques for enhanced security. The system uses a database of input samples for authentication, with an IR sensor detecting the presence of individuals. If the system identifies an unauthorized person, it prevents the vehicle from starting and triggers an alarm. The proposed system integrates face authentication and driving license verification using Arduino ATmega328 and deep neural networks, offering a significant advancement in preventing vehicle theft and accidents by ensuring only authorized users can operate the vehicle. Mounika et al. (2021) focus on a GPS and GSM-based system designed to reduce the time between vehicle accidents and the dispatch of emergency services, thereby improving survival rates. The system employs sensors such as Impact, Piezoelectric, and MEMS to detect accidents and immediately transmit the vehicle's GPS coordinates to emergency contacts. Additionally, the system enables vehicle tracking in case of theft, providing real-time location data to the owner via SMS, along with a link to Google Maps for easy retrieval of the vehicle's position.

Mao et al. (2021) address the security challenges in the Internet of Vehicles (IoV) by proposing an authentication scheme based on blockchain technology. The scheme uses the Hyperledger Fabric framework to enhance the security of identity authentication, leveraging blockchain's decentralization and data integrity features. By integrating cryptographic methods with blockchain, the proposed solution offers a robust alternative to traditional CA certification, improving the security and efficiency of vehicle identity verification in the IoV environment. Ravi et al. (2023) emphasized the potential for robots to replace human firefighters in dangerous situations. Their research introduced an Arduino-based firefighting robot equipped with automatic foam and water systems capable of detecting and extinguishing fires autonomously, thereby minimizing the risk to human life during fire emergencies. Maduka and Ibrahim (2023) addressed the escalating security challenges in Nigeria, highlighting the need for effective vehicle tracking systems. They reviewed existing microcontroller-based systems utilizing GPS and GSM modules to track vehicle movements. Their analysis pointed to the need for further research to improve system performance, cost-efficiency, and miniaturization.

Deepa et al. (2023) introduced a smart mobile application for vehicle tracking and speed warning. Their system, based on IoT, includes an ESP-32 microcontroller, cloud integration, and an Android application to monitor vehicle speed and send overspeeding alerts via GSM. The system's secure login feature ensures that only authorized users can access vehicle data. Adisa and Eludiora (2021) developed a Secured Vehicle Registration System (SVRS) that integrates fingerprint biometric technology to enhance anti-theft capabilities. Their system, designed using Unified Modeling Language (UML) and implemented with technologies such as JavaScript, PHP, and XAMPP SQLServer, demonstrated a high accuracy rate of 97.9% in authenticating vehicle owners, showcasing its effectiveness in linking vehicles to their rightful owners and preventing fraudulent activities.

Chimezie and Chukwudi (2020) explored the implementation of a computerized vehicle license registration system. Developed using Visual Basic.net 2012, their system allows for efficient management of vehicle registration and ownership transfers, reducing manual effort and streamlining the licensing process. The system's compatibility with Windows operating systems ensures its adaptability and scalability. Sethuraman and Santhanalakshmi (2020) focused on enhancing vehicle safety through an IoT-based Vehicle Black Box System (VBBS).

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This system monitors driver behavior and vehicle performance, providing real-time data to ensure safety and security. The integration of cameras and sensors within the vehicle allows for continuous monitoring, with data being sent to authorized personnel for immediate response in case of accidents, thereby improving post-accident care. The advent of the Internet of Vehicles (IoVs) has introduced new challenges in secure communication, which Vasudev et al. (2020) addressed by designing lightweight protocols for various IoV communication components. Their protocols ensure secure and efficient communication across Vehicle-to-Vehicle (V2V), Vehicle-to-Portable Device (V2P), Vehicle-to-Road Side Unit (V2R), Vehicle-to-Infrastructure (V2I), and Vehicle-to-Sensor (V2S) systems, demonstrating robust performance in terms of communication, storage, computation, and battery consumption.

Expanding on vehicle control and tracking, Naji et al. (2021) introduced a novel system for remotely tracking and controlling vehicles, particularly useful in stolen vehicle scenarios. Their system allowed for real-time location tracking using GPS coordinates and facilitated remote control by vehicle owners or law enforcement. Despite challenges such as network signal strength, the system showed promise in reducing police effort and improving response times.

Qahtan et al. (2022) focused on the energy management and monitoring system for electric vehicles using IoT technology. Their low-cost, real-time system was implemented using an ESP32 microcontroller and Blynk IoT platform. The system provided essential information on battery status, including capacity, charging current, and voltage, via a mobile application. The real-time updates and ease of use made the system a valuable tool for electric vehicle owners. Silas (2020) designed and implemented a digital breath alcohol detection system integrated with SMS alerts and vehicle tracking on Google Maps. The system detected alcohol levels in a driver's blood and prevented the vehicle from starting if the driver was intoxicated. Additionally, the system tracked the vehicle's location, aiming to reduce road accidents and associated fatalities caused by drunk driving. The project combined hardware and software components, including sensors, microcontrollers, and GPS/GSM modules, to achieve its safety objectives.

Gwalani et al. (2021) focused on a real-time vehicle detection and safety alarm system, utilizing Google TensorFlow Object Detection API and a mobile application built on Flutter. The system was tested in real-world scenarios in Mumbai, effectively detecting vehicles and triggering alarms during unsafe driving conditions. Although the system proved to be effective, it was primarily designed for highway scenarios, potentially limiting its use in other environments. Verma et al. (2024) focused on the management of GPS tracking systems in transportation, emphasizing the importance of effective system management for improved operational efficiency. The study explored various management components, including system configuration, data analysis, and performance evaluation. Challenges such as data quality, system reliability, and privacy concerns were addressed, with recommendations for robust data governance practices and stakeholder collaboration.

### 3. MATERIALS AND METHOD

#### 3.1 Materials

**Table 1: Hardware Components**

Component	Description
ARM 7 (LPC2148)	The LPC2141/42/44/46/48 microcontrollers are based on a 16-bit/32-bit ARM7TDMI-S CPU with embedded high-speed flash memory ranging from 32 kB to 512 kB. They are ideal for applications requiring miniaturization, such as access control.
MAX232	An interface standard (RS232) approved by the Electronics Industries Association (EIA) for connecting serial devices. It supports low-speed serial data communication between computers and related devices.
GSM Module	A module used to send coordinates received from GPS to a specified number. It includes a serial interface for controlling the modem using AT commands, and supports SMS transmission in automation systems or where GPRS services are unavailable.
SMS Transmission	Pre-stored SMS can be sent upon certain trigger events, such as in automation systems. This feature is also useful where small text data needs to be transmitted, such as in positioning systems or vending machines.

**Table 2: Software Requirement**

Software Requirement	Purpose
Arduino IDE	Programming the RFID modules
mySQL	Building and managing the database
Appcclerator	Developing the Android application
Slime Text Editor	Front-end development
Software Design	
	Ensured seamless interface with hardware components for smooth operation and real-time data exchange between the device and the NCS database
PHP	A scripting language used to build the backend logic of the application.
Bootstrap 5	A framework that simplifies the development of native applications using HTML, providing a user-friendly interface.
Sublime Text Editor	A text editor used for building the front end of the application, offering a clean and efficient coding environment.

#### 3.2 Methodology Adopted

##### 3.2.1 Design Overview

This paper designed and implemented an Android-powered smart duty payment and monitoring device which synchronized with the Nigeria Customs Service (NCS) database. Structured Systems Analysis and Design Methodology (SSADM) was adopted as the methodology to guide the development process. SSADM is a formal methodology for systems analysis and design. It divides system development into modules, stages, steps, and tasks to improve project control and system quality (Rouse, 2019, Osang et al 2023). SSADM is best suited for stable technical and business environments, following a top-down waterfall approach, but is less effective for highly dynamic projects.

In general, Radio Frequency Identification (RFID) will be used for tracking, tracing, and identifying objects. Vehicle duty payment, verification, identification and location will be achieved using a number of technologies: high-intensity light beacon (emitter/receiver system), radio beacon, VI systems based on GNSS (Global Navigation Satellite System) and cellular communications or other radio communication system, DSRC (Dedicated Short Range Communications), VI based on infrared beacon, inductive loop with vehicle mounted transmitter, inductive loop with vehicle classification algorithm, laser radar, VIP (Video Image Processing), VI based on sound detection systems, RFID (Radio Frequency Identifications) systems and WLAN-based Vehicle Identification. In this study PHP, Database (MySQL) are both working with Apache server (Xamp). The Software design used Macromedia Dreamweaver, firework, flash, and Switchmax. The block diagram of the system is shown in Figure 1.

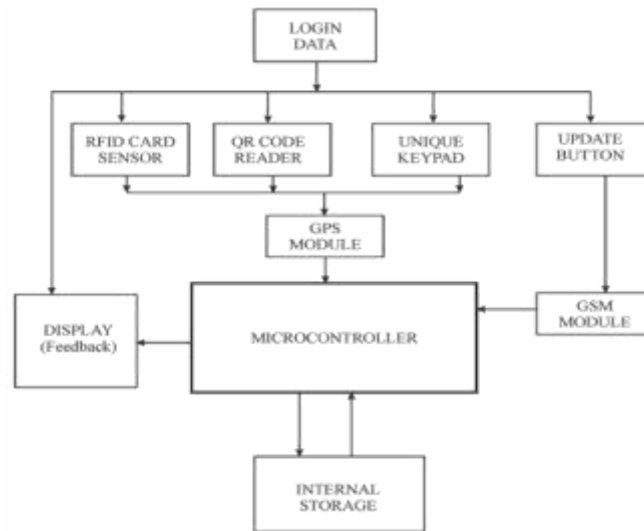


Figure 1. The block diagram of the device

### 3.2.2 Input Design

Input design focuses on what data the users (officers) will input into the system and how they will do it to ensure efficiency, accuracy, and completeness.

i). Key Inputs

- **Vehicle Information:** VIN (Vehicle Identification Number), Vehicle Make & Model, Year of Manufacture.
- **Payment Information:** Duty Payment Status (Paid/Not Paid), Payment Receipt Number, Amount Paid, Date of Payment.
- **Officer Information:** Officer ID (Service Number), Command, Location (using GPS).
- ii). Input Mechanism
- **Search Field:** Officers input the VIN or license plate number to retrieve vehicle payment status.
- **QR Code Scanner:** To scan vehicle documents for quick data input.
- **Dropdowns:** For selecting predefined vehicle make, model, or officer commands.
- **GPS Auto-fill:** Automatically capture officer location during patrols.

### 3.2.3 Choice of Development Environments

The choice of development environments was based on the need for compatibility, efficiency, and ease of integration. The Arduino IDE was chosen for its open-source platform and strong support for electronic prototyping. MySQL was selected for its robust database management capabilities, which were crucial for handling large volumes of data securely. Appcelerator was chosen for its ability to develop native Android applications with HTML codes, providing a flexible and powerful tool for building the system’s user interface and back-end functionalities.

### 3.2.4 System Flowchart

The flowchart of the system showing the logical flow of the mobile application is shown in Figure 2.

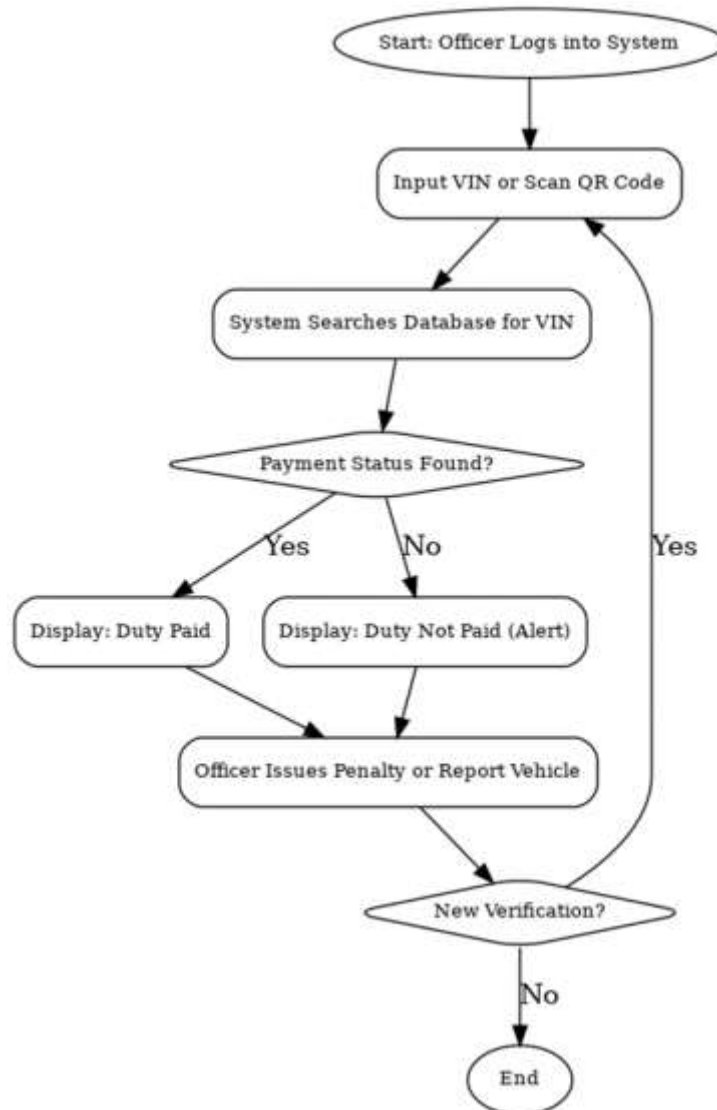


Figure 2. System Flow Chat

### 3.2.5 The Algorithm

- a. Officer logs into the system.
- b. Inputs VIN or scans QR code.
- c. System searches the database for duty payment status.
- d. If found:
  - Display “Payment Verified” with payment details.
  - Else, display “Duty Not Paid” alert.
- e. Officer takes action (issue penalty or report vehicle).
- f. Logout or start new verification.

### 3.2.6 Database Design

The design of database is to store essential vehicle, payment, and officer data.

Database Tables:

- a) **Vehicles:** vin (Primary Key), make, model, and year
- b) **Payments:** payment\_id (Primary Key), vin (Foreign Key), Payment reference, amount\_paid, payment\_status, payment\_date.
- c) **Officers:** officer\_id (Primary Key), name, service\_number, command, location.
- d) **Verification Log:** Log id (Primary Key), vin (Foreign Key), officer id (Foreign Key), verification date, location.

### 3.2.7 Use Case Diagram

The use case diagram illustrates the interaction between actors (officers) and the system. Here are key actors and actions:

#### Actors

- a) **Customs Officer:** Verifies vehicle duty.
- b) **System Admin:** Manages officers and payment records.

#### Use Cases

- **Login:** Officer logs into the system.
- **Verify Duty:** Officer searches by VIN or scans QR code.
- **View Payment Status:** Displays duty payment or unpaid status.
- **Generate Report:** Officer reports unpaid duty vehicles.
- **Logout:** Ends session.



Figure 3. Use Case Diagram

### 3.2.8 Object-Oriented Design (OOD)

Object-Oriented Design (OOD) involves defining the key classes and their attributes, methods, and relationships.

#### Key Classes:

a. Vehicle

**Attributes:** vin, make, model, year,

**Methods:** getVehicleDetails()

b. Payment

**Attributes:** payment\_id, vin, amount\_paid, payment\_status, payment\_date

**Methods:** checkPaymentStatus ()

c. Officer

**Attributes:** officer id, name, service number, command, location

**Methods:** login (), verify duty ()

d. Verification Log

**Attributes:** log id, vin, officer id, verification date, location

**Methods:** create Log ()

### 3.2.9 Entity Relationship Diagram (ERD)

The ERD will visually represent the relationships between your database entities. Entities and Relationships are as follows:

a. Vehicle (1) – (M) Payment: A vehicle can have multiple payments over time.

b. Officer (1) – (M) Verification Log: One officer can perform multiple verifications.

c. Vehicle (1) – (M) Verification \_Log: A vehicle can have multiple verification logs.

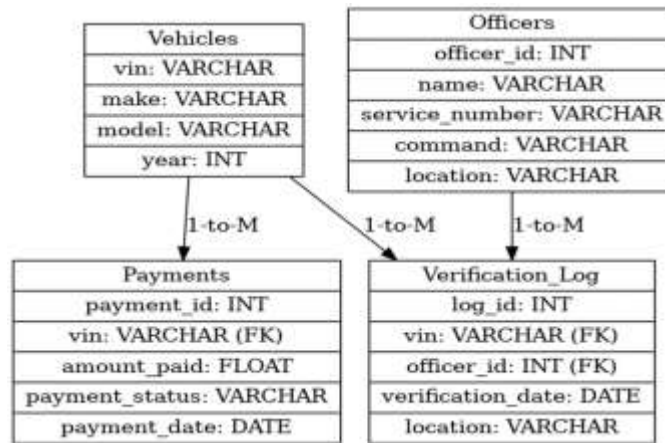


Figure 4. Entity Relationship Diagram (ERD)

3.2.10 Communication Flow

The Communication flow for the device is shown in Figure 5, while the circuit diagram of the device is shown in Figure 6.

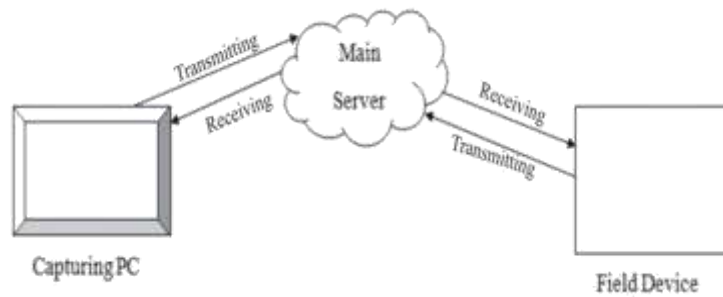


Figure 5. Communication flow chart of the device

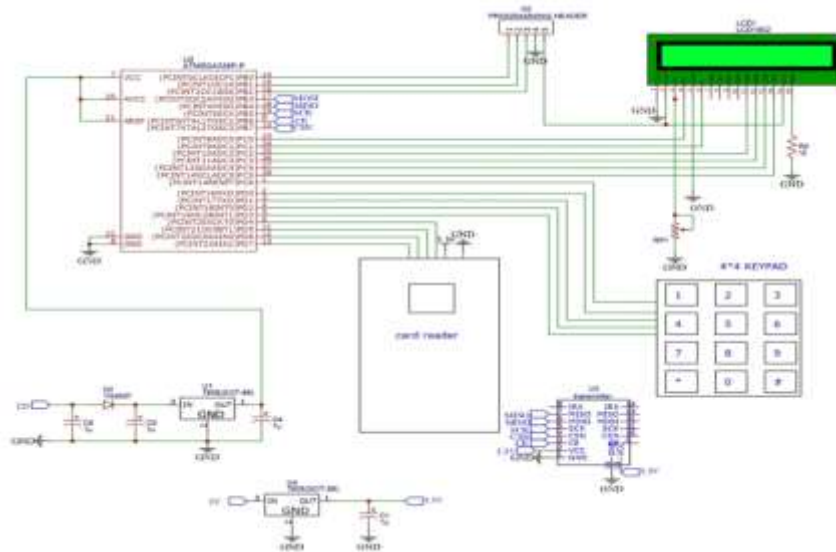


Figure 6: The Circuit diagram of the device

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## 4. RESULTS AND DISCUSSIONS

### 4.1 System Analysis

The system analysis involved assessing the requirements for real-time vehicle duty payment verification at customs checkpoints. Key components included the ARM 7 microcontroller for hardware integration, the Android application for user interface, and secure data synchronization with the NCS database.

### 4.2 System Design

The system was designed using a layered architecture, integrating hardware and software components. The design included the ARM 7 microcontroller for hardware operations, a secure API for data transmission, and a scalable structure to allow future enhancements.

#### 4.2.1 Front-End Design

The front-end design focused on a user-friendly Android application developed with Appcelerator. It enabled Customs officers to scan QR codes or manually enter vehicle details for real-time duty payment verification.

#### 4.2.2 Back-End Design

The back-end design included a robust application managing core functions such as user authentication, vehicle registration, and data processing. It ensured secure communication with the NCS database, real-time data verification, and consistent synchronization between field devices and the cloud server.

### 4.3 System Implementation

#### 4.3.1 Data Storage

All verified data is stored securely in the Customs database, ensuring a digital record of the verification process.

#### 4.3.2 System Requirements

The system required a combination of hardware and software components to function effectively. It was necessary to ensure that all components were compatible and capable of handling the expected workload. The system also required a secure connection to the NCS database, robust user authentication mechanisms, and real-time data processing capabilities to provide accurate and timely information during vehicle inspections.

#### 4.3.3 Hardware Requirements

The hardware components used in the project included RFID modules, RFID sensors, QR code cameras/readers, a Raspberry Pi HDMI display with touch capabilities, the Raspberry Pi RP2040 chipset, a 7.4V 3000mAh LiPo battery, and a GSM module for communication. These components were integrated into the Android-powered device to create a portable, efficient, and reliable system for customs officers to use in the field.

#### 4.4 Implementation Phase

The implementation phase involved the systematic execution of the system design and development plan. The process began with the assembly of hardware components, where the ARM 7 (LPC2148) microcontroller was integrated with the MAX232 interface for serial communication, and the GSM module was configured for sending SMS alerts and data transmission.

The software development followed, starting with the programming of the ARM 7 microcontroller using the Arduino IDE, ensuring it could efficiently handle tasks such as QR code scanning, RFID reading, and data synchronization with the NCS database. The Android application was then developed using Appcelerator, focusing on a user-friendly interface for customs officers. The application allowed for real-time verification of vehicle duty payments by scanning QR codes or manually entering vehicle details.

Following development, extensive testing was conducted to ensure the system's reliability and performance. Unit and integration tests were performed to verify that each software component operated correctly and that the system as a whole functioned seamlessly. The system's ability to handle large volumes of data, its real-time synchronization with the NCS database, and the effectiveness of its security measures were all thoroughly evaluated. Once testing was completed, the system was gradually rolled out through a phased changeover approach. This ensured a smooth transition from existing processes to the new automated system, minimizing disruptions and allowing for any necessary adjustments based on user feedback. Comprehensive training sessions were provided to customs officers, equipping them with the knowledge and skills needed to effectively operate the new system.

The implementation phase concluded with the successful deployment of the system across all customs checkpoints. Comprehensive training programs were conducted to equip Customs officers with the skills to effectively use the Android QR code scanning devices. These devices, now deployed at customs checkpoints and entry points, have significantly enhanced the efficiency and accuracy of vehicle duty payment monitoring and verification.

##### 4.4.1 Implementation Architecture

The implementation architecture consisted of a layered approach, integrating both hardware and software components into a cohesive system. At the core was the Android application, which interfaced with the RFID and QR code scanning hardware to capture vehicle duty payment information. The captured data was then sent through a secure API to the NCS database, where it was verified in real-time. It included:

**Android Application (Frontend):** This user-facing application provides a simple interface for customs officers to perform vehicle duty payment verification. It enables the scanning of QR codes or manual entry of vehicle details to retrieve and display real-time payment status. The frontend application communicates with the backend system and the NCS database to ensure data accuracy and up-to-date information.

**Backend Application:** The backend application manages the system's core functionalities, including user authentication, vehicle registration, and data processing. Upon logging in, users can register vehicles, and the backend application updates the database accordingly. It ensures secure communication with the frontend application and handles the integration with the NCS database for

real-time data verification. The backend also supports data synchronization, maintaining consistency between field devices and the cloud server.

The architecture also included a feedback mechanism for continuous system improvement, and a maintenance protocol to ensure long-term operational efficiency. The system was designed to be scalable, allowing for future enhancements and integration with other customs operations as needed.

#### 4.5 Software Testing

Software testing ensures that the system meets its requirements and functions correctly. The testing process includes unit testing, integration testing, system testing, and user acceptance testing (UAT).

- **Unit Testing:** Each component of the system was tested individually. For example, the login feature was tested to ensure that users with valid credentials could log in, while invalid users were denied access.
- **Integration Testing:** The interaction between different modules (e.g., user authentication, duty verification) was tested to ensure smooth functionality when combined.
- **System Testing:** The system as a whole was tested in a controlled environment, simulating real-world scenarios to ensure it performed as expected.

#### 4.6 Documentation

Proper documentation is critical to understanding, maintaining, and expanding the system. This includes:

- **System Design Document:** Outlines the architecture, data flow, and major components of the system.
- **API Documentation:** Provides details on the APIs used for vehicle duty verification, payment status, and report generation.
- **Installation Guide:** Instructions for setting up the system, including prerequisites, installation steps, and troubleshooting tips.
- **Developer Guide:** Documentation of the development environment, key libraries, and frameworks used (e.g., .NET, React.js).

##### 4.6.1 User Manual

The user manual provides step-by-step instructions for the system's end-users:

- a) **Logging In:** Go to the login page and enter your credentials (username and password). Press "Login" to access the system dashboard.
- b) **Verifying Vehicle Duty:** Enter the VIN in the search bar or scan the QR code. The system will display the vehicle's duty payment status.
- c) **Viewing Payment Status:** Navigate to the payment status section to view the payment history of any vehicle.
- d) **Generating Reports:** Click on the "Generate Report" button to view and export reports of unpaid duty vehicles.
- e) **Logging Out:** Click "Logout" to safely end your session.

#### 4.8 Hardware

The system can be deployed on standard server hardware with the following specifications:

##### 1. Server Hardware:

- Processor: Intel Xeon or equivalent (minimum 2.4 GHz, quad-core)
- Memory: 16 GB RAM
- Storage: 500 GB SSD
- Operating System: Linux or Windows Server (based on organizational preference)
- Network: Gigabit Ethernet connectivity

##### 2. Client Devices:

- The system is accessible via web browsers on standard desktop computers, laptops, or tablets. Minimum browser requirements include Chrome, Firefox, or Edge.

#### 4.9 Pictures of Stage-by-Stage Development

- a) Login Page Design: Initial wireframe and UI design of the login screen.
- b) Vehicle Duty Verification: Design phase showcasing input fields for VIN or QR code scanning.
- c) Payment Status Display: Sample design of how payment history is displayed.
- d) Report Generation: Early-stage mockup for generating reports on unpaid duties.
- e) Admin Dashboard: Admin panel design for managing officers and viewing payment records.
- f) Testing Interface: Screenshots of the testing environment, showing integration and UAT phases.
- g) Final System Interface: Finalized version of the system after successful testing and deployment.

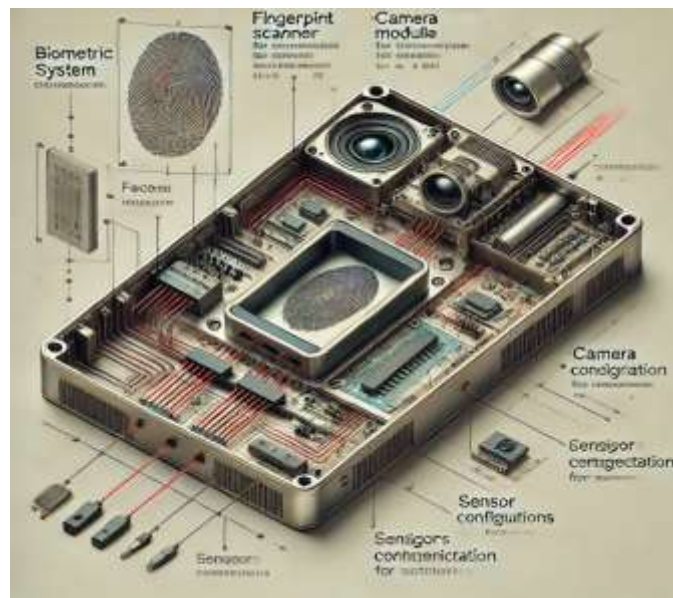


Figure 7. Circuit Diagram

Figure 8. Vehicle registration /Capturing Slip

Figure 8 is a prototype for the Vehicle Registration/Capturing Slip, which is integral to the system's verification process. It contains a unique QR code or RF card, generated upon duty payment, that serves as a digital proof of payment and a verification key for each vehicle and it displays the details of the vehicle including the make, model, year, status, engine type & number, VIN/ Chasis, Country of origin, Vreg Certificate Number, SGD number; the importers details which include name, TIN, and address as well as the clearance officer. This gives clarity to those involved in a vehicle and its registration process. During real-time vehicle duty payment monitoring at checkpoints, Customs officers use an Android device to scan the QR code or RF card on the slip. The scanning device, connected to the internet, performs real-time verification by linking the scanned data with the Customs database. This data is synchronized with the main cloud server, ensuring that records are consistently up-to-date and accurate.

**VEHICLE REGISTRATION - DUTY PAYMENT CERTIFICATE**

Make: LEXUS	Model: RX 350	
Year: 2020	Status: Used	
Engine Type: Petrol	Engine No: 2T2JZMDA9LC993208	
VIN/Chasis: 2T2JZMDA9LC993208	Country of Origin: United States	
VReg Certificate No: V6640-050123-224-YWT	SGD No: C1715	
Importer TIN: 22403498-0001	Importer Name: ABIJODUN OKUNLA LAGOS MAINLAND, LAGOS, AGEGE, LAGOS	
Importer Address: LAGOS MAINLAND, LAGOS	Clearance Office: PTML CUSTOMS OFFICE	
Clearance Code: 01TG		
<input type="button" value="Print"/>		

Figure 9. A Display of Details of a Registered Vehicle (Duty Payment Certificate)

Figure 9 is the interface that displays the details of a registered vehicle, specifically highlighting the Duty Payment Certificate. This represents the certificate presented to the vehicle owner. This screen is a crucial component of the Smart Vehicle Duty Payment Monitoring and Management System, enabling customs officers to verify a vehicle's duty payment status efficiently. The interface presents comprehensive information about the vehicle, including essential details such as the vehicle's make and model, year of manufacture, engine type, engine number, and VIN/Chassis number. Additionally, it provides the country of origin, Vehicle Registration Certificate number, Importer Tax Identification Number (TIN), importer's name and address, and the clearance certificate code.

When a customs officer scans the QR code on the vehicle's slip using an Android device, the device sends the scanned data to the Customs database through a secure API or web service. The database then retrieves the duty payment information linked to that specific QR code. This retrieved data is displayed on the interface and compared with the scanned QR code to verify the legitimacy of the duty payment. If the payment is confirmed, the vehicle is considered compliant with customs regulations. If a discrepancy or non-payment is detected, the system should automatically generate alerts, prompting Customs officers to conduct further inspection or take appropriate action.

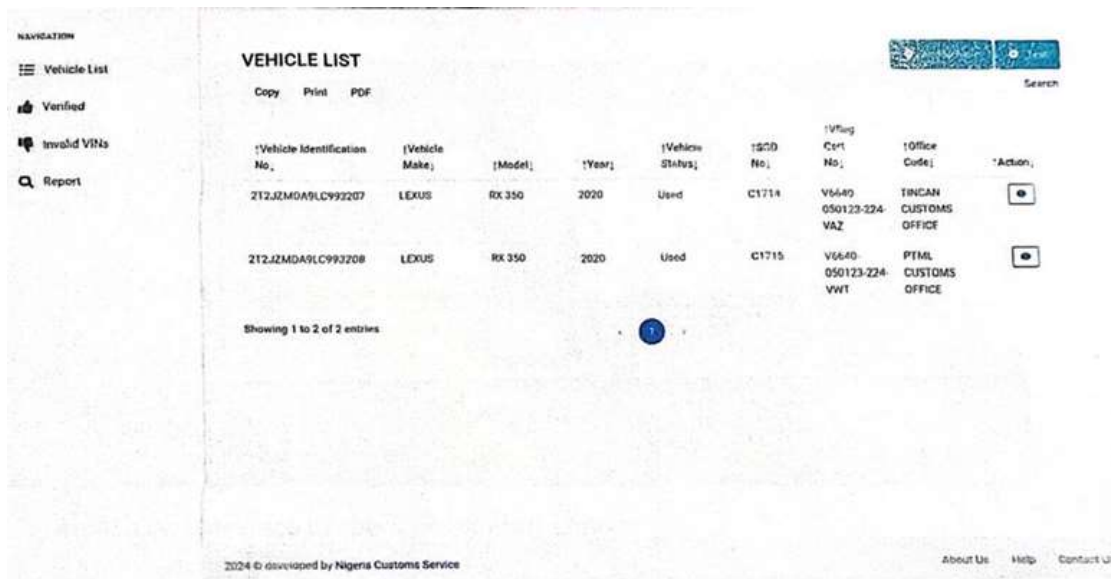
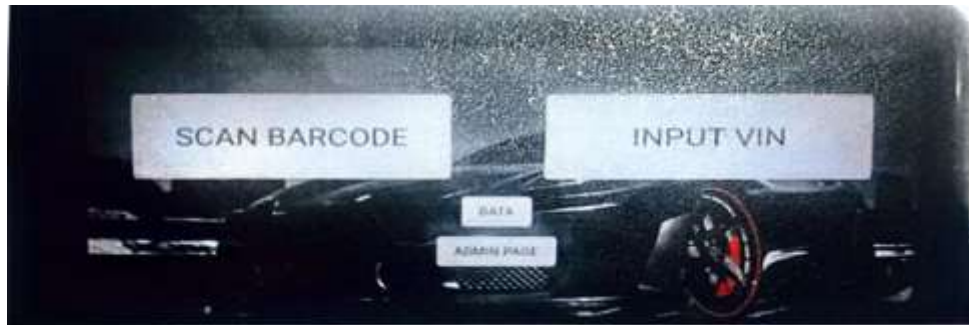


Figure 10. Display of Registered Vehicles

Figure 10 shows the interface used to display information about registered vehicles. This interface presents the summary of vehicles registered and captured in the database. The screen provides Customs officers with a comprehensive list of vehicles that have been registered and processed through the system. The display includes key details such as vehicle identification number, vehicle make, model, vehicle status, VReg Cert No and office Code.



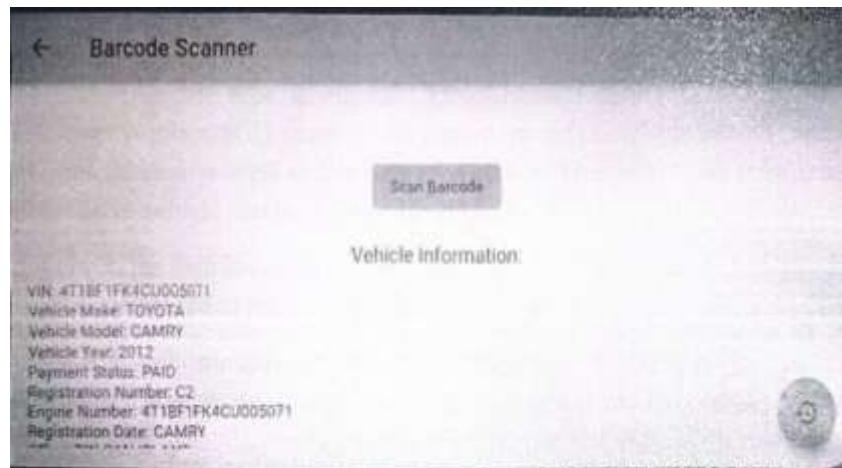
**Figure 11. The Interface of the Verification Device**

Figure 11 displays the interface of the verification device. This contained the login column where an admin can log in using his/ her username and password to perform duty payment verification. This interface is designed to streamline the vehicle verification process by offering three key functionalities. First, the "Scan Barcode" feature allows Customs officers to quickly scan QR codes or RF cards, instantly retrieving duty payment information linked to the scanned vehicle. Second, the "Input VIN" option provides a manual input field for entering the Vehicle Identification Number (VIN) if scanning is not feasible. Lastly, the "Data" and "Admin Page" sections enable access to detailed records and administrative controls, respectively. The "Data" page shows comprehensive vehicle and duty payment details, while the "Admin Page" offers settings and management options for the device.



**Figure 12. Synchronization View of Front End**

Figure 12 displayed the "Synchronization View of the Front End," showcasing the real-time data exchange between the verification device and the central system. This function allows for the update of all recently captured/registered vehicles before operation. This pulls the database to be available on the device for easy verification. This interface highlights how the front-end application manages the synchronization process to ensure accurate and up-to-date information. The view includes indicators for successful synchronization, data upload progress, and error alerts, providing Customs officers with clear feedback on the system's connectivity and performance.



**Figure 13. Display of QR scanned Result**

Figure 13 showcases the "Display of QR Scanned Result" interface, which is crucial for real-time vehicle verification within the Smart Vehicle Duty Payment Monitoring and Management System. This shows whether or not a vehicle is compliant with duty payment. Prominently featured in the top left-hand corner of the screen is the "Barcode Scanner," providing a central tool for scanning QR codes or RF cards. This section of the interface allows Customs officers to quickly initiate the scanning process. Once a QR code is scanned, the interface displays the resulting data, including detailed information about the vehicle's duty payment status. The screen updates dynamically to show verification results, such as payment confirmation or discrepancies, along with relevant vehicle details.

## 5. CONCLUSION

The methods used in this research involve capturing real-time vehicle duty payment information at checkpoints using an Android device equipped with QR codes or RF cards as unique verification keys. This approach ensures that each vehicle is accurately verified and its duty status is recorded instantaneously. Data synchronization between the field devices and the main cloud server is essential for maintaining up-to-date records and facilitating seamless data transfer. Verification logs from field officers, involved in patrol or enforcement activities, are collected to support enforcement actions and monitor compliance. These steps form a continuous loop, as the real-time data capture, synchronization, and logging processes are repeatedly executed to ensure that the system remains operational and responsive, providing consistent and reliable data for ongoing vehicle duty payment verification and enforcement. By maintaining this cycle, the system can promptly address discrepancies, update records, and ensure compliance with duty payment regulations. This study is in line with that of Ajodo (2015), and Sherifat et al. (2019).

The system was thoroughly tested, and its performance was evaluated against the specified requirements. Software testing included unit and integration tests to ensure the seamless operation of the system. The system changeover process was executed in phases to ensure a smooth transition to the new system, with comprehensive training provided to customs officers. The results demonstrate that the system is robust, reliable, and capable of enhancing the efficiency and effectiveness of vehicle duty payment monitoring and verification.

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