Undergraduate Final Year Analysis

Project Title: Toll Collection System for the Malawi Roads Fund Administration (RFA)

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Abstract

The current toll collection system at the Malawi Roads Fund Administration (RFA) mainly uses manual transactions that require vehicles to stop completely at toll booths. This slow process often causes traffic jams, frustrates drivers, and delays travel on busy highways. To address these problems of congestion and waiting times, a toll collection system that uses RFID (Radio Frequency Identification) technology was suggested. This system will include overhead installation of important components, such as high-resolution Optical Character Recognition (OCR) cameras and RFID sensors placed along the road. The OCR cameras will capture images of vehicles and their license plates, while the RFID sensors will read the unique RFID tags on each vehicle. This two-part system allows for quick identification and collection of important information about the vehicle and driver, including registration details, account status, and current balance. The hardware components will work together through an Arduino-based network, processing data in real time to handle toll transactions and penalty rule enforcement system. With this automated system, vehicles can keep moving without stopping at toll booths, assuming they have no outstanding balance, which will greatly reduce traffic congestion. Additionally, the system will have a grace period of up to one week and will be allowed for overdue payments before penalties are applied. Overall, the proposed toll collection system aims to create a more efficient and user-friendly experience for all road users, leading to smoother traffic flow and shorter travel times.

1 OVERVIEW

This report provides a comprehensive analysis of the organization's current toll collection system. It identifies the existing problems within this system and outlines a proposed solution to address these issues. Additionally, the report includes the methods used for gathering requirements that informed the development of the proposed system.

2 Requirements Gathering Methods

This section outlines the methods and techniques used for gathering requirements for the proposed system. The success of any project heavily depends on obtaining the correct requirements; in many cases, projects fail due to using incorrect specifications during development. Therefore, it is crucial to employ effective requirements gathering methods to ensure that the information aligns with the goals of the proposed system. In this instance, observation and interviews were the methods utilized to gather the requirements for the proposed system (Team Asana, 2025).

2.1 Observations

Observation is a qualitative data collection method in which the researcher systematically watches, listens to, and records behaviors, events, or conditions in their natural environment without manipulation or interference (Saunders, et al., 2019). This approach provides real-time insights into processes and interactions as they unfold, often uncovering contextual and unspoken dynamics that other methods may overlook. Direct observation was carried out at the toll gate and in some associated offices (Bryman, 2016). This method was particularly important for gathering information specifically about the:

- Current toll collection workflow
- Bottlenecks causing congestion.
- Common issues encountered by operators and drivers.
- Types of data handled during toll transactions.
- Typical user interactions with the toll infrastructure.

2.2 Interviews

An interview is a qualitative research technique that involves direct and purposeful conversations between the researcher and a participant, aimed at gathering detailed information about experiences, opinions, beliefs, or attitudes (Bryman, 2016). Interviews can be structured, semi-structured, or unstructured, which allows for flexibility in exploring the respondent's perspectives in depth. An interview was conducted with key stakeholders, including toll booth operators, system administrators, road users (drivers), and management staff from the RFA. This method facilitated a deeper exploration of user experiences, needs, and suggestions for improving the system (Saunders, et al., 2019). The following questions were designed for these interviews:

For Toll Booth Operators

- What steps do you currently follow to process toll payments?
- What are the most frequent challenges you face while collecting tolls?
- How long does it typically take to process a single vehicle?
- How do you handle situations when the system goes offline?
- Are there specific times when congestion is at its highest? Please describe.
- What information is required to process each vehicle?
- How do you currently record and resolve speed limit violations?

For System Administrators

- How do you manage and update information in the current toll collection system?
- What difficulties do you encounter with data retrieval or report generation?
- What are the current security concerns related to toll data?
- How is incident data (like speed limit breach) flagged and documented in the system?
- Would automation of payments and speed monitoring improve your workload? How?

For Drivers/Road Users

- How do you perceive the current toll payment process?
- What inconveniences do you experience at toll booths?
- What would make the toll payment process faster and more convenient for you?
- How do you feel about automated toll collection and speed monitoring?
- Do you have any concerns with RFID tag usage in your vehicle?

For RFA Management

- What are the strategic goals for toll collection efficiency?
- What performance metrics are used to assess current system operations?
- Are there any planned integrations with national vehicle databases?
- What penalties are currently in place for speed violations and non-payment?
- What level of automation and reporting is expected from a new system?

3 Detailed Current System

At present, toll collection at Roads Fund Administration (RFA) toll gates operates predominantly as a manual process with minimal technological support. Vehicles approaching the toll gate slow down and stop at the toll booth. Drivers must observe large physical boards that display static toll prices categorized by vehicle type, such as standard cars, buses, and trucks. There is no electronic vehicle categorization; all classification and charge determination rely on manual observation by toll collectors. Payment is almost exclusively in cash. Drivers hand over cash payments directly to toll booth staff, who manually count and verify the money. Mobile money payments are rarely accepted due to infrastructural limitations. Once payment is received, toll booth operators physically press a button to open the toll gate, allowing the vehicle to pass. Toll collectors issue handwritten or printed physical receipts as proof of payment. Staff also manually record the total number of vehicles processed and the cash collected on paper logs during their shifts. This data is then later compiled into manual reports submitted to RFA management for financial reconciliation and auditing. Dispute resolution, such as toll fee disagreements or payment issues, is handled face-to-face at the booth by staff. There is no automated system for notifications or reminders regarding toll price changes or payment dues. Additionally, no real-time traffic monitoring or analytics exist within the system, limiting operational insights. Security mechanisms for user authentication or verification of vehicle identity are absent. The system relies entirely on human observation and manual record-keeping. Traffic congestion often results due to slow manual processing and cash handling, and the manual nature exposes the system to human error and potential fraud.

4 Problems of the Current System

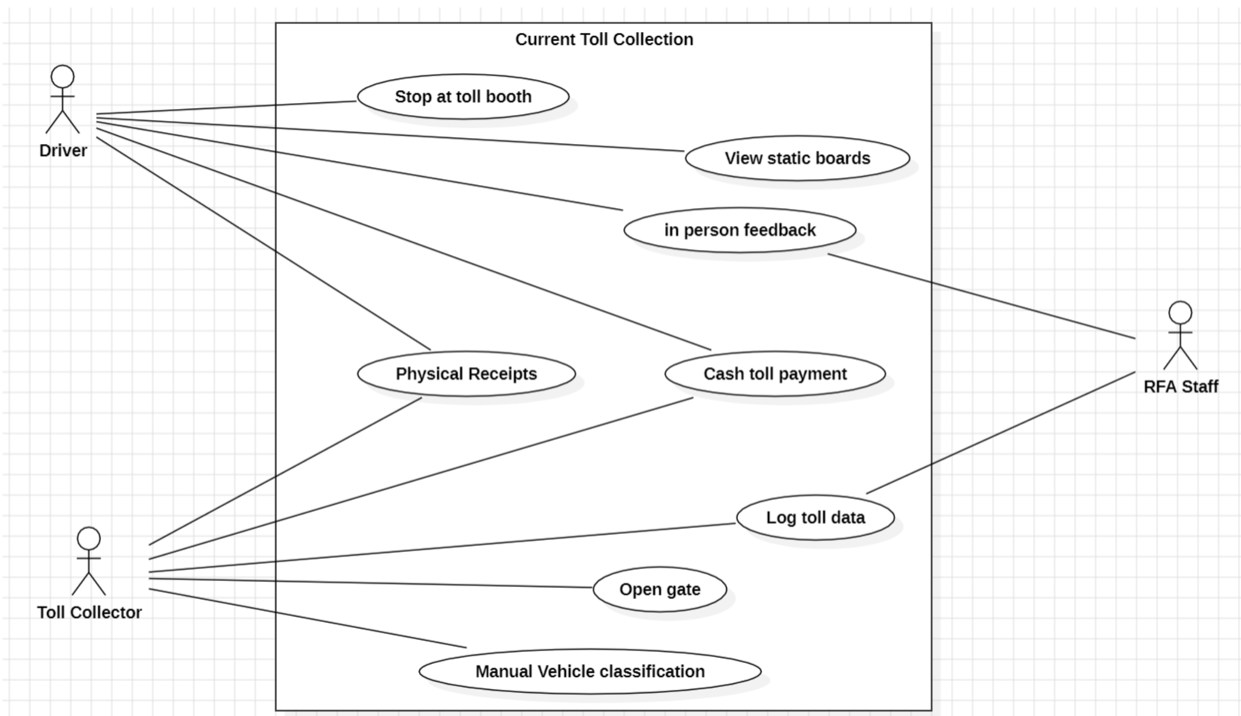
Despite its foundational role, the current toll collection system suffers from several weaknesses. It lacks proper user authentication, raising security risks and making it vulnerable to fraud. Manual vehicle classification leads to inefficiencies. The lack of automated vehicle categorization forces reliance on human judgment, causing delays and inaccuracies in toll charge assessments. Cash-only payments limit convenience and increase risks. Dependence on cash transactions increases vulnerability to theft, fraud, and errors, while limiting payment options convenient to users. Manual toll gate operation causes traffic delays. Toll gate opening by manual button control slows traffic flow and increases queue times during peak hours, reducing efficiency. Paper-based record keeping is prone to errors and delays. Manual logging and report compilation introduce risks of mistakes, fraud, and delayed data availability for management decisions. Lack of user authentication and vehicle identification reduces security. Without digital verification, driver identity and vehicle legitimacy cannot be guaranteed, increasing susceptibility to fraudulent activities. No automated notifications or communication limits user awareness. Important updates on toll price changes or account balances are communicated manually or infrequently, reducing timely user action. No Real-Time reporting or analytics impairs operational oversight. Absence of immediate data on collections and traffic patterns prevents proactive management and system optimization. Dispute resolution is manual and inefficient. Handling payment or classification disputes face-to-face is time-consuming and may cause extended traffic disruptions. Static toll pricing does not adapt to traffic or market conditions. Current toll charges remain fixed, missing opportunities to optimize revenue or manage congestion through variable pricing.

5 Proposed Solution

To develop a web app that will help in toll collection through vehicle categorization, car weight measurement, payment gate control, payment grace period, dynamic toll pricing based on traffic and time, multi-channel payment options, penalty and enforcement system, emergency vehicle priority, and exception rules, which will greatly improve the system to an extent.

6 Use Case of the Current System

Figure 1 Current System Use Case



6.1 Description

7 Functional Requirements

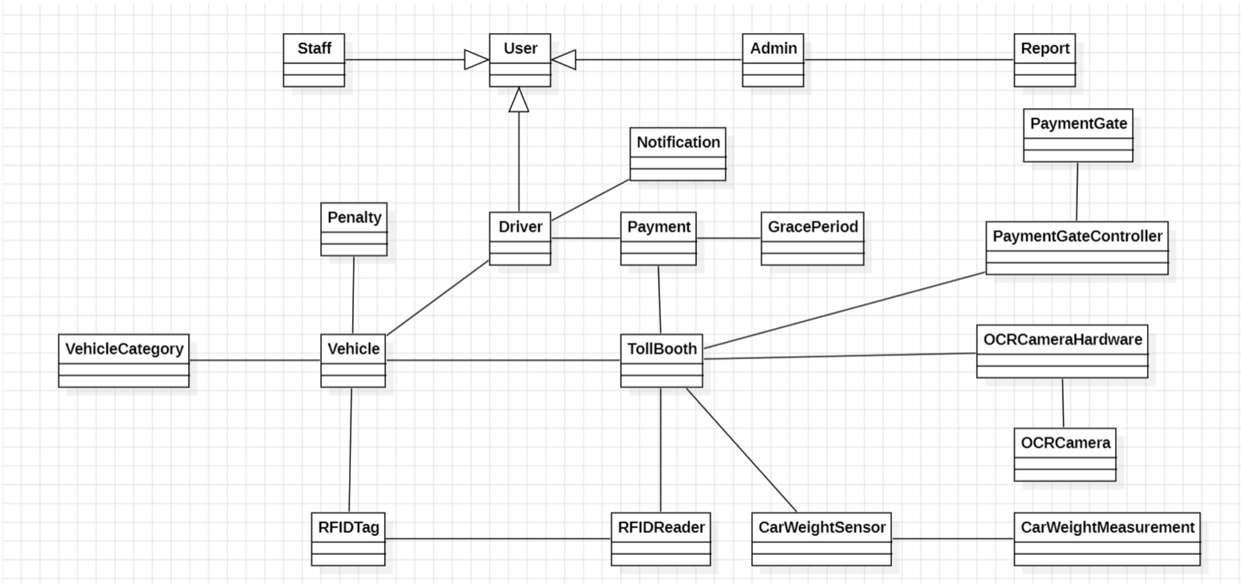
- **Authentication** - It will incorporate multiple user roles, including Drivers, Staff, and Admin, each authenticated securely for access control.
- **Vehicle Categorization** - Vehicle categorization will be automated by size, with dedicated toll rates assigned dynamically based on traffic conditions, special dates, or inflationary adjustments.
- **Car Weight Measurement** – The system will have stations that will assess vehicles weight as they approach the toll booth to apply correct charges and penalties for overweight vehicles.
- **Payment Gate Control** – This will prevent gate opening if vehicle accounts have insufficient funds, enforcing payment compliance.
- **Payment Grace Period** - A grace period of up to one week will be allowed for overdue payments before penalties are applied.
- **RFID and OCR Technology** - OCR cameras and RFID tags on number plates will automate vehicle identification, speeding up processing and enabling real-time tracking.
- **Multi-Channel Payment Options** – The system will consist of multiple payment channels, including online payments, mobile money integration, bank cards, and cashless wallets, to maximize convenience.
- **Emergency Vehicle Priority and Exception Rules** - Exemption rules will be included for government vehicles, emergency responders, and frequent users.
- **Real-Time Notifications and Reminders** - The system will feature real-time notifications and reminders for drivers about toll price changes, low balance alerts, and upcoming road maintenance or policy updates.
- **Reports and Analytics** - Advanced analytics and reporting dashboards will provide administrators with daily collections, traffic patterns, vehicle classifications, revenue trends, and health system metrics.
- **Invoices and Receipts** - Invoices and receipts will be generated electronically alongside physical copies for redundancies.

8 Non-Functional Requirements

- **System performance:** The system must maintain a rapid response time for transactions, ideally processing each within 2 seconds to ensure a smooth user experience.
- **Scalability:** The architecture should accommodate future growth, capable of efficiently supporting up to 100,000 vehicles concurrently without performance degradation.
- **Security measures:** Implementation of stringent security protocols, including data encryption and secure access mechanisms, to protect sensitive information and prevent unauthorized access.
- **Reliability:** The system must demonstrate high reliability with an uptime of 99.9% or greater, ensuring it is consistently available for users.
- **Usability:** The user interface should be designed with user experience in mind, featuring an intuitive layout that is accessible on all devices, from desktops to mobile phones.
- **Compliance:** Meticulous adherence to all pertinent state and federal regulations governing toll collection and data privacy, ensuring the system operates within legal and ethical guidelines.

9 Initial Class Diagram For The Proposed System

Figure 2 Initial Class Diagram Proposed



9.1 Description

10 References

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11 APPENDIX