



American Journal of Innovation in Science and Engineering (AJISE)

ISSN: 2158-7205 (ONLINE)

VOLUME 4 ISSUE 1 (2025)



PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

Solar-Powered Automated Toll Collection System and Integrating Weight Sensor for the Safety of a Bridge

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Article Information

Received: July 12, 2024

Accepted: August 24, 2024

Published: February 05, 2025

Keywords

Arduino, RFID, Solar, Toll Collection

ABSTRACT

This research will explore an RFID-Based Smart Automatic Weight-Based Toll Collection System designed to address traffic issues and enhance transparency in toll collection. Our goal is to develop a digital toll collection system that is both time-efficient and automated. The research focuses on a weight-based toll collection system using radio frequency identification (RFID) technology. In this system, RFID tags mounted on vehicle windshields are scanned by RFID readers to retrieve embedded information, eliminating the need for manual ticket payments and toll fee collections by authorities. This system facilitates smooth data exchange between vehicle owners and toll authorities, leading to more efficient toll collection, reduced traffic, and minimized human errors. Additionally, the research includes a weight sensor to measure vehicle weight, blocking access to overweight vehicles.

INTRODUCTION

The traditional toll collection system relies on manual toll collection, where a toll collector stationed in a booth physically collects payments from drivers (Patil, 2021). This method is slow, often leading to traffic congestion. Typically, one or two individuals manage the booth, stopping each vehicle to collect the toll and issuing a receipt as proof of payment (Xu *et al.*, 2007). Without a centralized control system, this approach can result in discrepancies, preventing the government from accurately receiving all toll revenue. The primary goal of this project is to develop an advanced toll collection system that is more efficient, automated, and time-saving. Additionally, weight sensors have been incorporated to monitor vehicle weight, ensuring the safety of roads and bridges (Shahrier *et al.*, 2024).

A quick toll collection system is essential to improve traffic flow, reduce congestion, and enhance overall efficiency on busy roads. Traditional toll collection methods often lead to long queues, causing significant delays, increasing fuel consumption, and contributing to environmental pollution due to idling vehicles (Segun *et al.*, 2017). A faster, automated toll system minimizes these delays, allowing vehicles to pass through toll points more smoothly and reducing the likelihood of traffic jams. Moreover, it enhances the accuracy and transparency of toll transactions, reducing the potential for human error or fraud. By streamlining the toll collection process, a quick system saves drivers time and supports road infrastructure maintenance and development by ensuring consistent and reliable revenue collection (Haque *et al.*, 2020). The RFID-Based Electronic Toll Collection System is a highly effective and straightforward innovation. It features an In-Vehicle Unit (IVU) installed on the vehicle's front windshield, which holds a payment card. When the vehicle approaches the toll plaza, the

RFID reader or antenna scans the IVU. The payment can be made either in advance or after passing through the toll, and the system can operate with or without physical barriers (Haque *et al.*, 2020). This RFID-based system offers more data capacity compared to barcodes, ensures faster reading speeds, and has a lower risk of fraud.

LITERATURE REVIEW

The Barcode-Based Electronic Toll Collection System is a subtype of Dedicated Short-Range Communication (DSRC) systems. In this system, a barcoded sticker is affixed to the vehicle and scanned by a laser as it passes through the toll plaza, demonstrating a typical DSRC application for electronic tolling (Kim & Kang, 2007). While barcodes are widely used in various sectors-such as libraries for book management, shopping centers for tracking sales, and the food industry for storing product information-this technology has significant drawbacks when applied to toll collection. These include limited reliability, reduced accuracy in adverse weather conditions, lack of flexibility, slower data reading rates, minimal storage capacity, and susceptibility to theft (Iqbal *et al.*, 2019).

Another approach is the VPS technique, which combines a global satellite navigation system with a communication mechanism. This system operates using a GPS unit installed in the vehicle, connected to an onboard unit (OBU) that stores the vehicle's coordinates and transmits transaction data to toll authorities via GSM.

The VPS system is highly reliable, accurate, and efficient, with performance unaffected by environmental conditions. However, it has notable drawbacks, including high installation, operational, and maintenance costs, the need for careful handling, and additional power requirements and accessories (Iqbal *et al.*, 2019).

This situation creates a challenge in determining whether

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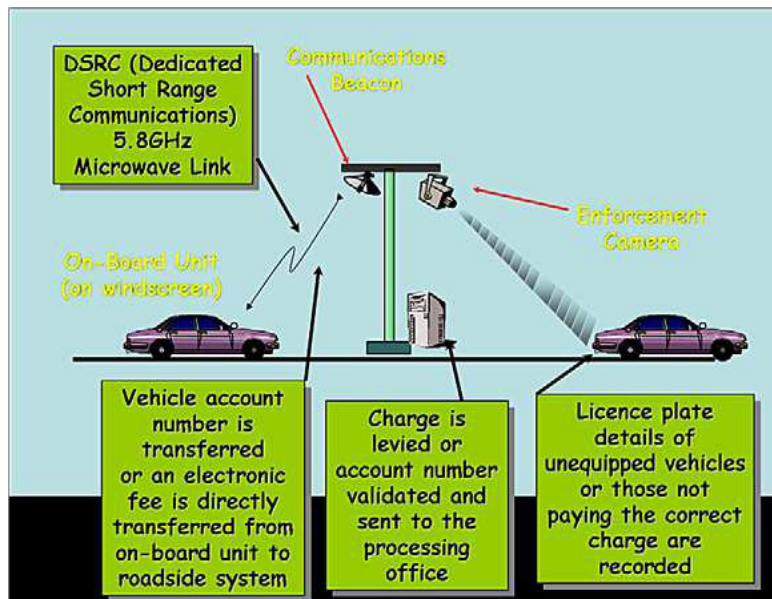


Figure 1: DSRC system for electronic tolling

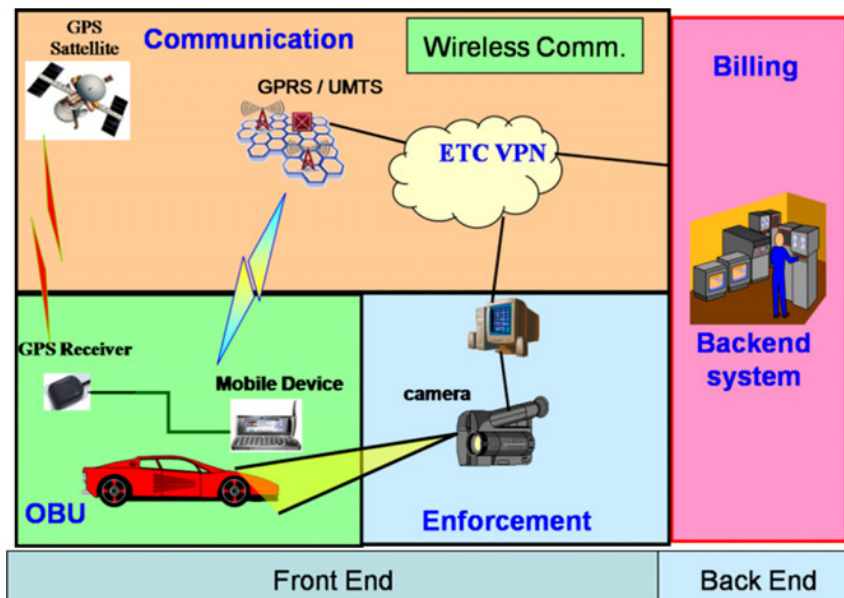


Figure 2: VPS system for electronic tolling (Iqbal *et al.*, 2019)

to choose the best option among existing technologies or to develop a new one. When there is uncertainty and difficulty in selecting the optimal solution, the idea of adopting a hybrid technology often arises (Soni *et al.*, 2018). This uncertainty can also discourage policymakers from embracing new and advanced technologies, as a single wrong decision could lead to significant problems for future generations, resulting in wasted time and money. Therefore, it becomes crucial to accurately predict the best solution by employing a highly subjective decision-making technique to identify the most suitable alternative.

MATERIALS AND METHODS

When a government collaborates with private companies to construct roads, they often enter into various agreements where toll collection is implemented to recoup the investment made by these private entities. In

Bangladesh, the construction of infrastructure like the Meghna Bridge, Dhaka Elevated Expressway, Gulistan-Jatrabari Flyover, and Mukhtarpur Bridge has been carried out through such partnerships. Currently, these bridges are managed and maintained by the respective private companies (Rodrigo & Hewage, 2022).

In this system, we will install a weight sensor to monitor the weight of vehicles on roads, flyovers, and bridges. Overweight vehicles often travel on these routes, potentially compromising the structural integrity over time. To ensure uninterrupted operation, the system is also equipped with a solar battery backup in case of a power outage (Xu *et al.*, 2007).

In Bangladesh, the current toll collection system is time-consuming, as drivers must physically hand over cash to the toll cashier, often leading to significant traffic congestion in toll areas. This system can be frustrating,



Figure 3: Proposed area (Meghna Bridge Toll Booth)

as no one wants to waste valuable time. In contrast, the proposed system is highly time-efficient, automatically processing payments and sending travelers a notification on their phones with the amount deducted from their cards. This eliminates the need for drivers to spend time handling cash or requesting receipts (Hoque Khan, 2019) The proposed toll system minimizes the risk of corruption as it operates entirely through electronic devices. It is also environmentally friendly, as vehicles do not need to stop to pay tolls, which reduces harmful emissions. In contrast, the current system allows all vehicles to pass through bridges regardless of their weight, potentially risking damage to the infrastructure (Shahrier *et al.*, 2024). Our proposed system includes a weight sensor that detects overweight vehicles and generates an alert if a vehicle exceeds the weight limit, preventing it from crossing the bridge. This helps protect the bridge from potential

damage and extends its lifespan. The installation of the weight sensor before the toll plaza ensures the bridge remains safe and secure from structural harm.

RESULTS AND DISCUSSION

Accurate information about all project equipment and software is crucial. In this system, the Arduino Mega R3 2560 is the core component, as it houses all the programming and controls. We use a GSM module with a SIM900A unit to transmit data to the toll plaza and vehicle owners' phones. RFID technology is implemented to register all vehicles. A servo motor is employed to raise and lower the barrier after toll payment is completed. Additionally, a weight sensor is included to measure vehicle weight and determine whether the vehicle can cross the bridge or must use a bypass route.

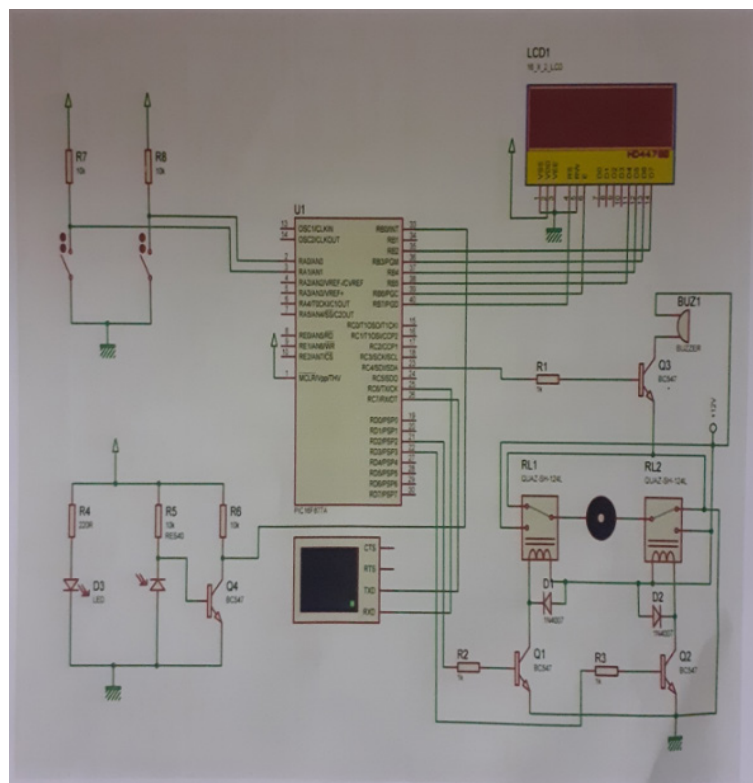


Figure 4: Project Circuit Diagram

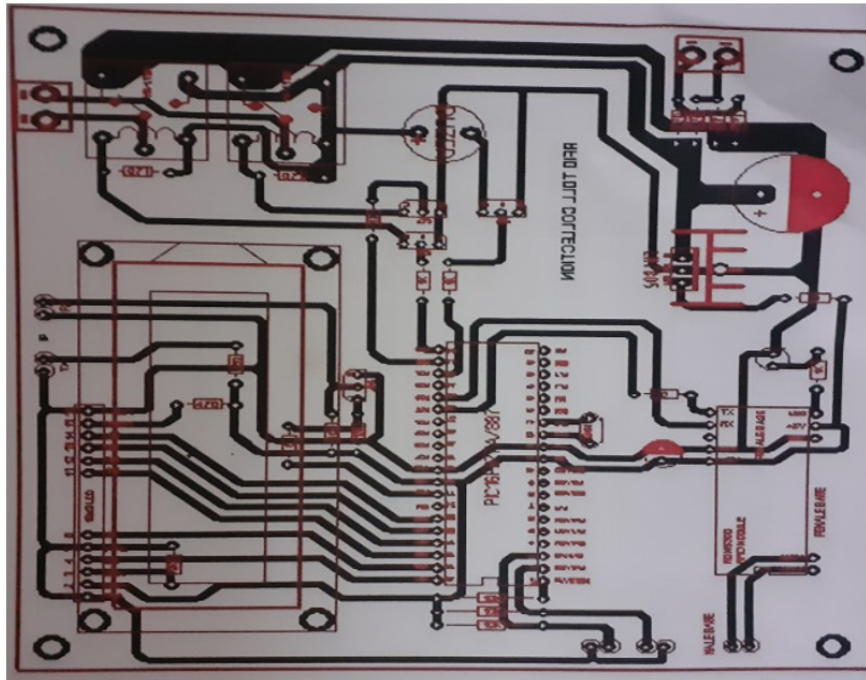


Figure 5: PCB layout of the project

Figure 4 illustrates the circuit diagram of the project. On the other hand, figure 5 shows the PCB design of the project. The system is powered by a solar panel, ensuring a renewable energy source. Other components include a buzzer, LCD display, battery, and laser.

When a vehicle crosses the entry gate, it interrupts the infrared (IR) rays, causing the gate to close. The gate remains closed until the IR rays are re-established. Once the rays are reconnected, the gate opens. The RFID tag provides the vehicle's number, which is detected by the RFID reader and sent to the controller. The load sensor measures the vehicle's weight, helping to identify whether it is a light or heavy vehicle. Based on this information, the

toll amount is automatically deducted. Simultaneously, the exit gate opens automatically to allow the vehicle to pass through. The entire toll payment process takes less than one minute, typically around 20-30 seconds. Information regarding the vehicle owner's account balance and whether the vehicle is authorized to pass will be sent via SMS to the owner's phone. The computer display provides real-time updates on passing vehicles, including toll payment records. Each time a vehicle passes, the total toll amount is automatically updated. At the end of each 24 hours, the total toll collected is recorded in a separate text file. This file details the overall toll amount and specifies how much each vehicle has paid.

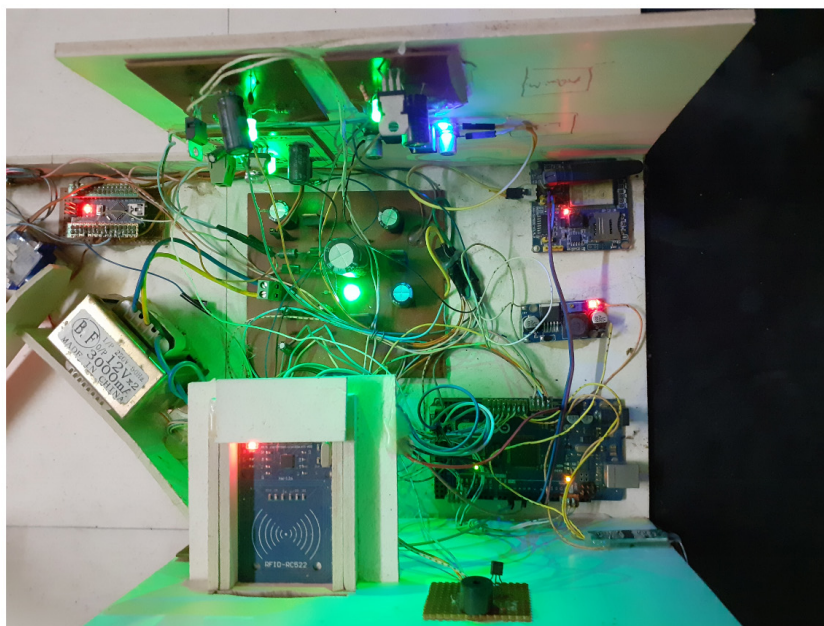


Figure 6: Physical Image of Project

CONCLUSION

A study of this research indicates that implementing the ETC system would be advantageous for both the country and its citizens (Lee *et al.*, 2008). Key benefits of the proposed system include time and fuel savings, energy efficiency through solar power, and reduced vehicle congestion at toll areas, all while supporting the sustainability of bridges. Moreover, this system helps prevent financial losses from fraud or theft for the government or private sector owners. Additionally, the weight sensor continuously monitors and protects the bridge from potential damage or accidents, such as collapses.

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