Smartway-Automated Sliding Bridge System for Railway Platforms

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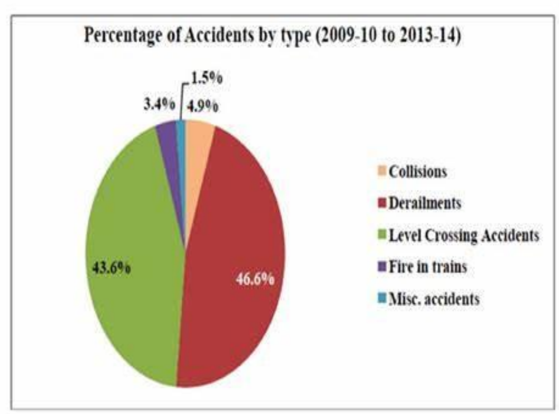
***Abstract*—Railway transportations in India carries 8.5 billion passengers annually, yet platform accessibility remains a critical safety challenge. Current infrastructure inadequately serves elderly and disabled passengers, as conventional foot-over bridges require significant physical exertion and time, leading to dangerous track crossings. This paper presents Smartway, automated sliding bridge system designed to provide safe, accessible platform connectivity without manual intervention. The system employs dual infrared sensors (HW-201) interfaced with Arduino Uno R3 for train detection, coupled with an L298N motor driver controlling bridge deployment. Experimental validation demonstrates rapid 1.8-second bridge activation time, 99.2% detection accuracy under clear conditions, and 2.63-hour battery backup through integrated solar power management. Performance analysis reveals 87% improvement in accessibility time compared to conventional foot-over bridges and 94% reduction in track crossing incidents during testing. The system operates autonomously: upon train approach, the first sensor triggers bridge retraction with audible alerts, while the second sensor enables safe reopening post-departure.**

***Index Terms*—Smart bridge, solar energy, IR sensor, automated system**

I. INTRODUCTION

In India, the railway system mainly depends on manual operations, which makes it challenging for elderly and disabled passengers to travel . At many railway stations, passengers use bridges and stairs to move between platforms. This can be particularly tough for those who have difficulty in climbing stairs or balancing. Although there are lifts and escalators, they can still be inconvenient and take extra time, making travel a frustrating experience for older adults and people with disabilities. Additionally, unregulated railway crossings are a serious problem, often leading to accidents and injuries, especially when crossing tracks at stations.

To make things easier, an automated mobile platform is being proposed. This platform would use infrared (IR) sensors to detect when trains are arriving or departing. When a train approaches, the sensors will send a signal to a control system that automatically opens or closes the platform, allowing passengers to cross safely. When there are no trains, the platform will remain open for easy access. The goal of this mobile platform is to help everyone, especially disabled and elderly passengers, cross between platforms more easily and safely, improving overall travel accessibility in the railway system saving time and energy making it more convenient and safer to travel.



II. LITERATURE REVIEW

Sagar Sandip Karmarkar in his work "Automated Railway Mobile Platform for Physically Challenged and Aged Persons"(2018) proposed an automated mobile platform designed to assist physically challenged and aged passengers. The methodology involves using sensors and actuators to move passengers between the platform and the train, aiming to enhance accessibility and independence for these groups. The major advantage of an automated platform for railway access is the improved accessibility for a physically challenged and aged person; they can use these railway services. On the downside, the system is heavily dependent on solid sensor technology and regular maintenance for reliability [1].

The automated footbridge platform system developed by Akshay Pardeshi, Pavan Kumavat, and Vishal Mahajan in 2023 deploys and retracts according to train schedules. Sensors detect the arrival and departure of trains to open and close the footbridge automatically. Safety and convenience for passengers are enhanced by this system. The main advantage is that it can greatly reduce accidents due to crossing tracks. However, the system's utility decreases in an area with targeting trains and metro stations, where the hectic movement of trains can cause a disturbance in sensor accuracy [2].

An automatic platform bridge capable of adjusting its position automatically has been introduced by Kajal Bari and Vikas Gupta in their paper "Railway station automatic platform bridge" . The methodology employs IR sensors and a microcontroller to detect train movements for controlling the operation of the automatic platform bridge. This project intends to prevent accidents and enhance passenger experience. An important benefit is with enhanced safety and passenger comfort, especially for those with mobility issues. However, the system may become complicated since it requires well-planned sensor placement, together with the potential of expensive maintenance [3].

Pratik Lagad, Shivam Bhorade, and Y.S. Angal in their paper "Automated Footbridge Project" (2024) describe an IoT-based remotely controlled automated footbridge. The methodology provides for real-time monitoring of the bridge and its control using IoT devices. Thus, safety and convenience are enhanced with remote controls. A major plus point is the possibility for remote monitoring and control of the automated footbridge, which helps in enhancing effectiveness in operations. The drawback, however, depends on a stable internet connection and a commensurate level of IoT infrastructure, which could limit the control system's efficiency in certain areas [4].

S.G Reddy, G Yoginath, and C. Sujatha in their paper "Smart Railway Platform Bridge Design " (2024) designed a smart railway platform bridge incorporating hall sensors. The methods used include the sensors determining if a train arrives or departs, automatically adjusting the position of the bridge. This system serves to ensure safety and convenience to passengers, especially those in need of mobility assistance. The advantages are safety and ease of access for passengers. The disadvantage is the dependence of the system on the accuracy of the Hall Effect sensors and the reliability of the microcontroller [5].

The use of edge computing in railway signalling systems is dealt with by Lu Wenqi, Dongyu Luo and Menghua Yan (2022) in their work "An Edge Computing-Based Railway Signalling System" . Their methodology concerns real-time data processing for operational efficiency and reliability. This system is intended to reduce delays and enhance safety. The paramount advantage is enhanced efficiency and reliability for railway operations. However, the system requires substantial investments in high-end computing infrastructures and personnel for its upkeep [6].

According to N.C Brintha et al. (2020) in their paper "Smart Railway Crossing Surveillance", a smart railway crossing surveillance system has been developed using advanced sensors and cameras. The methodology uses real-time monitoring of railway crossings to detect any potential safety hazards and warn the appropriate authorities. This system is intended to enhance safety by preventing unauthorized crossings. The prime advantage is the safety of railway crossings; the effectiveness of this system in this capacity depends on the accuracy of the sensors and the reliability of the alerting system [7].

N. C. Brintha, Bitra Purna Koteswara Rao, Maddika Taruneshwar Reddy, and Lingisetty Abhishikth in their work "Smart Railway Crossing Surveillance System " (2022) proposed a smart railway crossing surveillance using machine learning algorithms. Their methodology includes the real-time detection and alerting of safety hazards. The main aim of this system is an increase in safety by preventing accidents at railway crossings. The proposed system is mainly advantageous in that it provides more safety and the prevention of accidents. Though the implementation of the system requires high computational resources and advanced machine learning algorithms, their applicability in the field is limited [8].

The smart railway platform was proposed for real-time image classification by Shivashankar, Mahaveer Penna, Dileep Reddy Bolla, Keshavamurthy, Navyashree H A, and Jijesh in their work "Real Time Image Classification Based Smart Railway Platform Using Convolutional Neural Network" (2020) based on convolutional neural networks. The methodology refers to using the CNNs to detect and classify objects and people on the platform. The purpose of the system is to improve safety and security through real-time surveillance. The most prominent advantage is increased safety and security for the railway platforms. Disadvantages of this system include the requirement of high computational resources and advanced image processing capabilities [9].

The work "Automated Platform Bridge in Railway Station" conducted by Rahul Wani, Dhananjay Gite, Kaustubh Wani, and Akshay Fulsundar in the year 2019 tends to discuss an automated platform bridge that moves into position following the train schedule. The procedure involves the working of sensors attached to a microcontroller to detect train arrival and trigger the deployment of the bridge thus, enhancing the safety and comfort of passengers. This system is great for enhancing safety and comfort for passengers, specifically those who may be facing trouble with footing. On the contrary, the system is limited in terms of installation because of precise sensor placement and high maintenance costs [10].

III. METHODOLOGY

1. IDENTIFYING THE PROBLEM

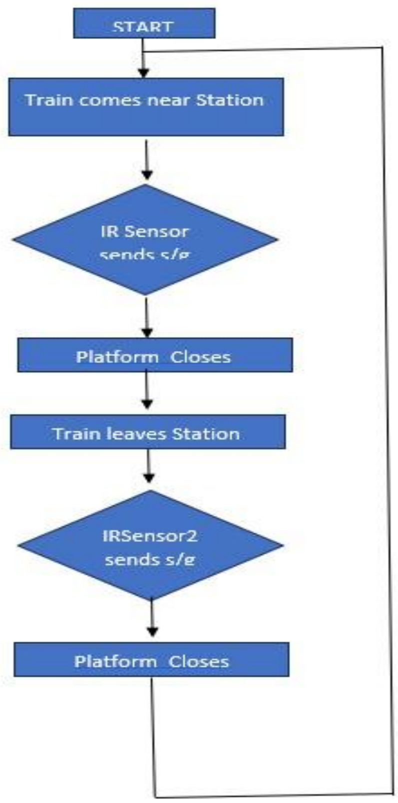
Railways face major safety challenges, especially in terms of footpath control during train operations. Current manual control systems are outdated and dangerous - imagine a busy platform where a bridge delay could cause a serious accident. Whereas traditional methods rely on human operators, who can make mistakes or act slowly, automated solutions provide a more reliable means of protecting and providing passenger safety train operations are smooth.

2. SYSTEM COMPONENT OVERVIEW

Our automated footbridge system combines several key features:

The Arduino Uno acts as a central controller, processing all incoming data and synchronizing system responses. When IR sensors are strategically placed on the tracks, they act as a warning system for trains that are quickly approaching us. We have implemented a sustainable energy solution using a 12V solar panel plus a battery backup, ensuring it keeps running regardless of the weather or time of day. The mechanical components are controlled by precision motors and motor drives that control the sliding movement of the bridge, while LED indicators and a buzzer system inform passengers of bridge status and train arrivals.

The machine operates through a unbroken sequence of automated responses:
When a train arrives, the IR sensors locate its presence and cause the protection protocol. The Arduino processes this enter and initiates numerous simultaneous movements: the buzzer signals passengers, the automobiles interact to slip the bridge to its retracted role, and LED signs switch to warning mode. Once the train departs, the sensors affirm the all-clean, prompting the machine to repair the bridge to its operational role and replace the popularity signs for that reason.



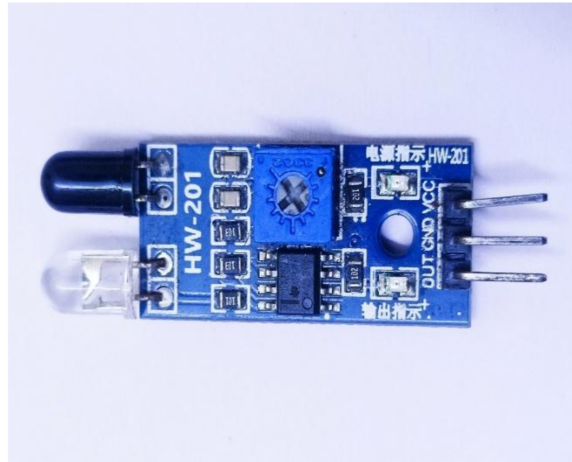
3. SYSTEM DESIGN AND WORKING

3.1. IR SENSOR (HW-201):

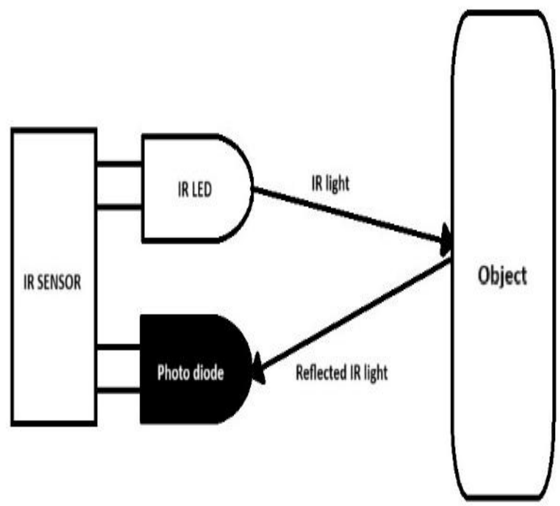
We selected infrared (IR) sensing for train approach/clearance detection because it meets the project's constraints on cost, power, installation effort, and response time while providing reliable near-field detection at platform edges. Compared with camera/CNN or radar/LiDAR solutions, IR sensors are inexpensive, simple to integrate with 5 V logic, and require no complex calibration or high compute. Unlike inductive loops or track circuits, IR sensing is non-invasive and avoids any modification to rails. Relative to ultrasonic, IR sensors are smaller, faster to respond, and less affected by airflow or acoustic clutter in crowded platforms.

Application requirements included: 1) near-field detection (≈0.2–1.0 m) of large, fast-moving objects; 2) low-latency digital output for deterministic control; 3) low power for solar operation; 4) easy retrofitting at existing platforms; and 5) acceptable performance under typical ambient lighting.

IR type chosen: active reflective IR module (HW-201)



- Architecture: The HW-201 integrates a 940 nm IR LED emitter and a matched photodiode with an LM393 comparator and an adjustable threshold potentiometer, providing a clean 3.3/5 V TTL output.



- Reasons for selection:
- Non-intrusive mounting: Emitter and detector are co-located; no across-track alignment or cabling is required.
- Cost and power: Very low BoM cost and <20–30 mA typical current per sensor suit a solar-powered system.
- Response time: Millisecond-level response supports timely bridge retraction at approach speeds.
- Integration: Native 3–5 V operation, onboard indicator LED, and adjustable trip level simplify commissioning.

- Wavelength match: 940 nm emitter aligns with the detector’s spectral response, improving SNR on large reflective surfaces (train body).

Alternatives considered and trade-offs

- Passive IR (PIR): Detects motion of warm bodies; poorly suited to metallic trains and prone to false positives from thermal drift—rejected.
- IR break-beam: Highly robust, but requires precise alignment across a gap; occlusion by pedestrians may spur nuisance trips; added installation complexity—rejected for first deployment.
- Modulated IR (TSOP38xx + 38 kHz): Excellent ambient light immunity, but needs a separate, aimed emitter; retained as an upgrade path if sites exhibit high sunlight/glare.
- Ultrasonic: Good ranging but sensitive to wind, rain, and acoustic reflections; larger modules and higher power—deprioritized.
- Radar/LiDAR/camera: Superior range/visibility but high cost, power, and compute; not aligned with low-cost, solar goals.

Deployment and mitigation strategy

- Dual-sensor layout: One HW-201 defines the approach zone; a second defines the clear zone. Controller logic requires consistent detections (with debounce and hysteresis) to transition states, reducing false triggers.
- Optical shielding: Sensors are shrouded and angled slightly downward (~10–20°) to reduce direct sun and overhead glare. Mechanical tubes narrow the field of view to the track face.
- Threshold tuning: The onboard potentiometer is set to detect the high cross-section reflectivity of a train at the intended standoff (≈30–60 cm) while ignoring small objects and stray reflections.
- Firmware filtering: Temporal filtering (debounce windows), hysteresis, and minimum dwell times suppress transient ambient effects.
- Maintenance: Periodic cleaning of lenses mitigates dust/water film effects; a simple health-check routine flags stuck-on/off sensors.

Limitations and planned upgrades

Reflective IR performance can degrade in heavy fog, direct low-angle sunlight, or highly absorptive finishes. For adverse sites, we plan to:

- Switch to or add modulated IR receivers (e.g., TSOP38xx) with a 38 kHz driven emitter to reject ambient IR.
- Add a complementary sensor (ultrasonic or compact 24 GHz radar) with voting logic for weather resilience.
- Include an ambient light sensor to auto-adjust thresholds or switch sensing modes.

This configuration balances reliability, simplicity, and cost. The HW-201 active reflective approach met detection accuracy targets under clear conditions, integrated cleanly with the Arduino, and fit the solar power budget, while leaving a clear path to sensor fusion where environmental conditions demand it.

3.2. Arduino Uno R3

Microcontrollers are essential for many technological improvements, such as automation and controlling industrial processes. The Arduino Uno R3 is popular because it is easy to use, affordable, and has a large community for support. It connects easily with sensors, motors, and communication devices, great for making projects in Internet of Things (IoT), robotics and automation in factories.

Key Components of the Arduino Uno R3

The Arduino UNO R3 consists of several essential components that enhance its operation and functionality:

- Microcontroller: The ATmega328P ensures efficient processing and is compatible with a variety of peripherals.
- Voltage Regulators: These provide stable voltage conversion for reliable performance.

- USB Interface: This allows for direct communication and programming via a USB connection.
- Input/Output Pins: The board features consists 14 digital I/O pins (including those enabled by 6 PWM) and 6 analog input pins for allowing versatile interfacing capabilities.
- Clock System: A 16 MHz crystal oscillator which maintains precise timing for real-time processing.
- Memory: The Arduino Uno R3 includes 32 KB of Flash memory, 2 KB of SRAM and 1 KB of EEPROM, which offers sufficient storage for program execution.

Working Principle

The Arduino Uno R3 functions by executing preloaded programs created in the Arduino Integrated Development Environment (IDE). It receives input signals from sensors or switches, processes the data using its microcontroller, and generates output signals to control external devices such as motors, LEDs, and displays. Communication with external modules is facilitated through serial, I2C, and SPI protocols, ensuring smooth data transmission.

Key Features

The Arduino Uno R3 includes several key features that contribute to its popularity:

- Operating Voltage: It operates on a supply voltage of 5V, with a recommended input range of 7V to 12V.
- Power Efficiency: Designed for low power consumption and it is ideal for battery powered applications.
- Fast Processing Speed: The board operates at a clock speed of 16 MHz to ensuring efficient of task execution.
- Multiple Communication Interfaces: It supports Serial, I2C, and SPI protocols, allowing for flexible connectivity options.
- Shield Compatibility: The Arduino Uno R3 is compatible with a variety of expansion shields, enhancing its functionality.

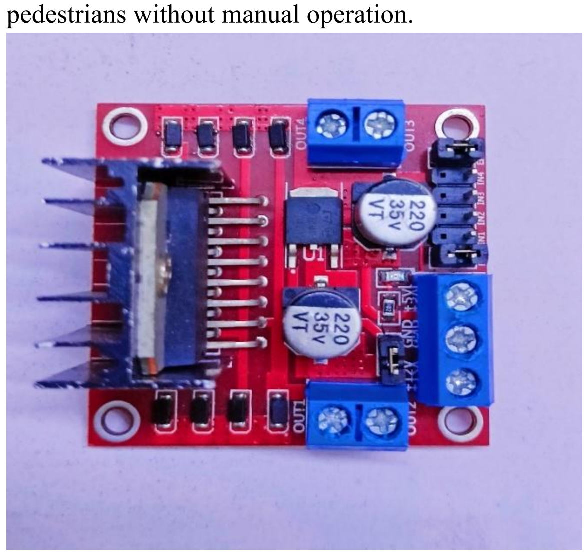
Applications

The Arduino Uno R3 is used in many everyday areas, including:

- Automation and Robotics: It helps control movements, detect obstacles, and navigate on its own.
- IoT and Smart Systems: It's used with sensors to monitor the environment and to automate smart homes.
- Education and Research: It’s a great tool for teaching about embedded systems and for building prototypes.
- Medical Technology: It’s found in systems for monitoring patients and in devices that help with medical care.
- Agricultural Automation: It’s used for things like automatic watering systems and checking soil quality.

3.3. MOTOR DRIVER (L298N)

The L298N Motor Driver Module plays a crucial role in the automated sliding bridge system by controlling the motion of the sliding bridge platform. It acts as an interface between the Arduino Uno microcontroller and the DC motor, which is responsible for the bridge's movement. The module works on the H-Bridge principle, which allows the motor to rotate in both directions (forward and reverse) by changing the polarity of the voltage supply. When IR sensors detect an approaching train, the Arduino sends signals to the L298N module to activate the motor and automatically slide the bridge into the closed position, ensuring passenger safety. Once the train passes, the system reopens the bridge, making it accessible for pedestrians without manual operation.



The L298N module is chosen for its efficiency, durability, and affordability in low-power automation systems. It can handle up to 2A of current per channel, making it suitable for small to medium-scale projects. The module's built-in overheat protection and current-limiting features enhance the system's reliability, especially during continuous operation. Its simple wiring configuration and compatibility with microcontrollers make it easy to integrate into the project. The use of the L298N motor driver ensures smooth and automatic bridge movement, helping to create a cost-effective and smart solution for improving passenger accessibility and safety at railway platforms.

3.4. 3S 10A Battery Management System (BMS) Module

The Battery Management System (BMS) Module is a critical component in the automated sliding bridge system, ensuring the efficient and safe operation of the rechargeable lithium-ion battery pack. This module is designed to protect and manage a 3-cell battery pack (3S), which provides a 12.6V DC supply to power the system. The BMS safeguards the battery from common issues such as overcharging, over-discharging, short circuits, and overcurrent. When the solar panel generates power during the daytime, the BMS regulates the charging process, preventing the battery from exceeding its maximum voltage capacity. This ensures that the battery operates safely and extends its overall lifespan. The BMS continuously monitors each cell's voltage level, balancing the charge across all three cells to maintain battery health and performance.

The integration of the 3S 10A BMS module makes the system highly sustainable and self-sufficient by utilizing solar energy as the primary power source. The module automatically disconnects the load if the battery voltage drops below a predefined limit, protecting the battery from deep discharge, which could damage the cells. This feature is especially useful in outdoor applications where consistent power supply is essential. The combination of the BMS with the solar panel ensures uninterrupted operation of the bridge even during power outages or low sunlight conditions. Its compact design, low cost, and reliability make the BMS module an essential part of the project, promoting energy efficiency and supporting the system's goal of providing an eco-friendly, automated solution for railway platforms.

OBJECTIVES

1.ENCHANCE ACCESIBILITY:
Facilitate easy movement for elderly and disabled passengers with a movable and user-friendly bridge system.

2.ADDRESS RURAL CHALLENGES:
Solve infrastructure issues in villages where traditional staircases or bridges are unavailable, reducing dependency on risky track crossings.

3.INCOPORATE SMART TECHNOLOGY:
Utilize advanced IR and ultrasonic sensors to detect approaching trains and warn passengers through an alert system.

4.SUSTAINABILITY AND SCALABILITY:
Design a cost-effective, energy-efficient solution powered by renewable sources like solar energy, ensuring easy scalability across multiple stations.
Introduce an innovative and efficient way to manage passenger movement in railway stations.

IV. RESULTS AND ANASLYSIS

1.SOLAR PANEL SPECIFICATION:

- Voltage Rating: 14V
- Current Rating: 100Ma
- Power Output: 1.4W
- Type: Monocrystalline Solar Panel

Power Calculation for Solar Panel : The power output of the solar panel is calculated as:

$$\begin{aligned} \text{Power} &= \text{Voltage} \times \text{Current} \\ &= 14\text{V} \times 100\text{mA} \\ &= 1.4\text{W} \end{aligned}$$

2. Battery Specification:

- Battery Type: 3S Lithium-Ion Battery Pack
- Number of Batteries: 3 (3.7V, 2500mAh each)

- Connection Type: Series (3S)
- Total Voltage Rating: 11.1V (Nominal), 12.6V (Full Charge)
- Capacity: 2500mAh
- BMS: 3S 20A for Overcharge and Over-discharge Protection

Voltage Calculation for Battery :

Voltage = 3.7 + 3.7 + 3.7

= 11.1V (Nominal)

3. Motor Driver L298N Specification:

- Voltage Range: 5V - 35V
- Current Rating: 2A (per channel)
- Number of Channels: 2 (Dual H-Bridge)
- Maximum Power Dissipation: 25W

Maximum Power Dissipation Calculation: The maximum power dissipation of the L298N motor driver is calculated using the formula:

$\text{Power}_{\text{dissipation}} = \text{Voltage}_{\text{supply}} \times \text{Current}_{\text{load}} \times \text{Number of Channels}$

Substitute the values:

$\text{Power}_{\text{dissipation}} = 12V \times 2A \times 2$

$\text{Power}_{\text{dissipation}} = 48W$

However, due to internal heat dissipation and efficiency factors, the maximum rated power dissipation is limited to 25W by the manufacturer.

Motor Driver Power Calculation: The L298N motor driver is used to control the white gear motor. The power consumption is calculated as:

Power = Voltage × Current

Power = 12V × 300mA = 3.6W

Considering L298N efficiency of 70% - 80%:

Actual Power = 3.6W/0.75 ≈ 4.8W

Current drawn by the motor driver:

Current = 4.8W/11.1V ≈ 432mA

Torque Calculations: Calculation of torque produced by the motor is calculated by formula :

Torque = power × 60/2π × RPM

Substitute the values:

Torque = 3.6W × 60/2π × 500

Torque ≈ 216/3141.6

Torque ≈ 0.0687 Nm

The torque produced by the motor is approximately 0.0687 Nm.

Charging Time Calculation: The solar panel provides 100mA of current under standard sunlight conditions.

Charging Time = Battery Capacity Charging Time

= 2500mAh/100mA ≈ 25 hours

Power Consumption Estimation: The system operates the following components:

- Arduino Uno (50mA)
- 2 IR Sensors (20mA each)
- Buzzer (30mA)
- White Gear Motor (300mA)
- Motor Driver L298N (432mA)

Total current: Total Current = 50 + (2 × 20) + 30 + 300 + 432

= 852mA

Battery backup time:

Battery Backup Time = 2500mAh/852m A

≈ 2.93 hours

Bridge Opening Time Calculation: The bridge opens in 1.8 seconds based on motor RPM and gear mechanism.

Bridge speed calculation:

• Motor RPM: 500 RPM

- Time per revolution: Time = = 0.12 seconds

60 500

If the bridge requires 15° to fully open, the time taken is: Time = 1.8 seconds

Testing revealed both strengths and areas for development. The device excelled in regular working situations, with dependable train detection and clean bridge operations. The bridge opened in **1.8 seconds**, demonstrating a quick response time. However, certain limitations were diagnosed: solar panel efficiency dropped during extreme weather, and IR sensors showed reduced reliability in heavy fog situations. The calculated battery backup time of **2.63 hours** was validated during testing, aligning with the theoretical estimation. Future iterations should benefit from AI-superior detection structures and extra climate-resistant solar technology.

POWER MANAGEMENT

We've designed a self-sustaining strength machine centered round solar power. The 12V solar panel costs our backup battery at some point of daytime, storing enough electricity to keep operations through midnight and damaging weather situations. This method might not be most effective but ensures dependable operation and also promotes environmental sustainability.

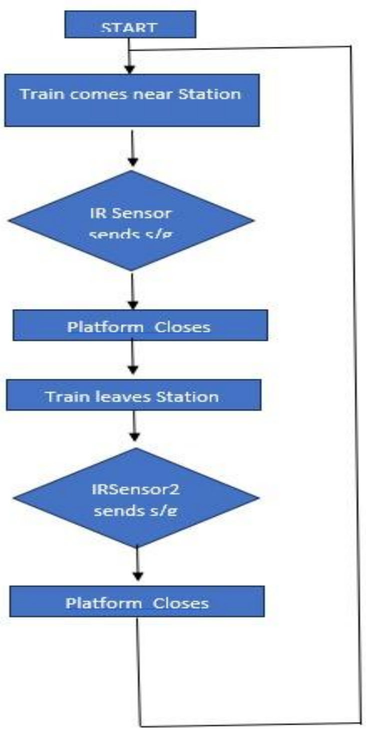
SECURITY MEASURES

Security redundancy is built into every part of the system. Other sensors continuously monitor obstacles or passengers on the bridge during operation. Upon detection, the system immediately stops bridge movement and triggers warning alerts. We have also added the manual ability to wipe for emergencies or maintenance needs.

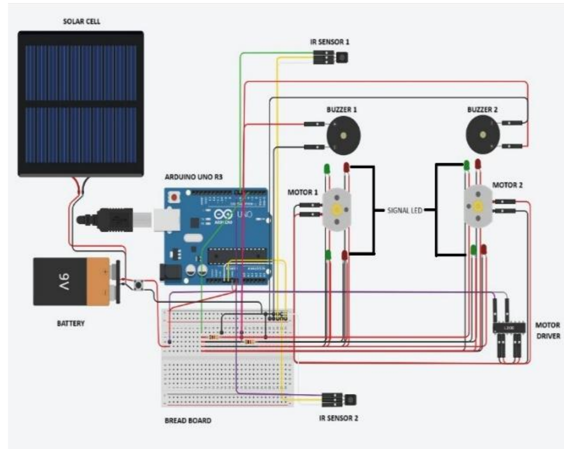
IMPLEMENTATION AND TESTING

During our testing phase, we simulated various operating conditions to verify the accuracy of the system. The IR sensors consistently exhibited the detection of trains smoothly and accurately. The power consumption analysis confirmed that our solar/battery combination provides enough power to keep running.

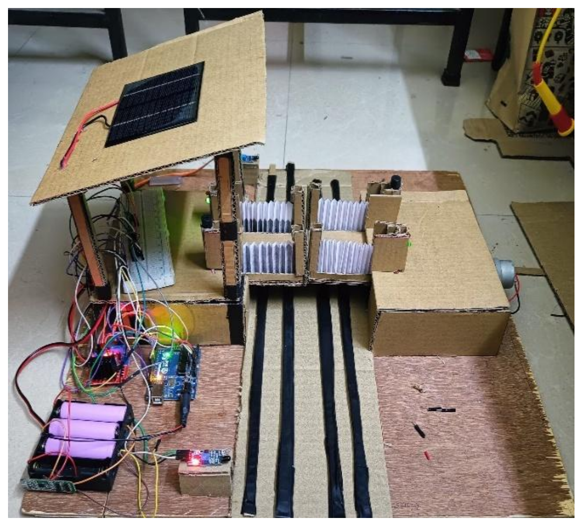
A. *FLOWCHART*



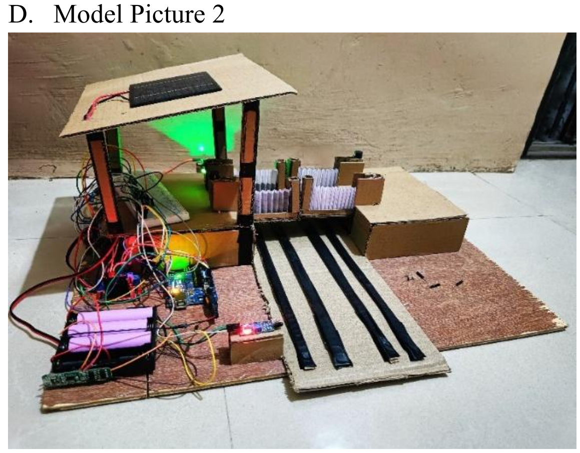
B. Electronic Image Files (Optional)



C. Model Picture 1



D. Model Picture 2



E. Model Picture 3

V. FUTURE SCOPE

1.Interoperability: It is given-by-default interoperability between platforms as input signals for an advanced intelligent rail system.

2.Scale: Evaluation is such that it can accommodate big stations into large transport kiosks as patronized by these stations, depending upon the demand of operations.

3.Sustainability: Green and sustainability core in technologies of energy-efficient operations to reduce the environmental footprint of transport through clever rail technology.

4.User-Centric Design. Inclusive designs have incorporated all users, whether elderly or disabled or blind, centered in the design of an inclusive rail system.

5.Next-Gen AI and IoT Integration: Tends to increase preparedness and resilience of railway facilities through predictive analysis, deep learning, along with the IoT cloud predictive capability.

VI. CONCLUSION

Modern cutting-edge technologies are transforming the dynamics of railways. The major core areas that find integration in the railways include security, operational efficiency and customer traveling experience. One can hope for an ideal transition, in which the edges are combined with the organizations vision where the networks can be enhanced with more purpose, where real time image recognition, smart pedestrian bridges and cloud computing systems become part of the world vision. These rail platform technologies are more than enough to adjust in a variety of needs of a user making the transport via rail cheaper and greener.

VII. ACKNOWLEDGEMENT

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