



International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 22 No. 4 (2026)



ijerst.editor@gmail.com
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Research Paper**Automated [Zero Manpower] Railway Crossing-2**

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Abstract

Railway level crossings are critical interfaces between railway tracks and road traffic. Conventional manually operated level crossings require continuous human presence for monitoring train movement, operating gates, providing warnings, and managing road traffic. Human error, delayed response, poor visibility, fatigue, and communication failures can increase the risk of accidents. This paper proposes an Automated Zero-Manpower Railway Crossing (AZMRC) system in which train detection, warning generation, gate operation, obstacle monitoring, and remote status reporting are performed automatically.

The proposed system uses a combination of railway-compatible train-detection sensors, obstacle-detection sensors, a safety-oriented control unit, automatic barriers, warning lights, audible alarms, emergency controls, and wireless communication. The system detects an approaching train, determines its direction and estimated arrival, activates road-user warnings, closes the barriers after ensuring that the crossing is clear, continuously monitors the crossing area, and reopens the barriers only after the train has completely cleared the protected section. A redundant sensing approach is proposed so that failure of an individual sensor does not result in an unsafe gate operation.

Recent research demonstrates the feasibility of combining infrared/ultrasonic sensing, long-range wireless communication, microcontrollers, and automatic gate control for railway crossings. IEEE Xplore+1 Indian Railway specifications also emphasize level-crossing monitoring, warning arrangements, gate control, communication, and failure indication. RDSO+1 The proposed system therefore focuses not merely on automatic gate movement but on a fail-safe, redundant and remotely supervised railway-crossing architecture.

Keywords: Railway Level Crossing, Zero Manpower, Automatic Gate, Train Detection, Obstacle Detection, IoT, Wireless Communication, Railway Safety, Embedded System, Fail-Safe Control.

Introduction

Railways provide an efficient and high-capacity mode of transportation, but railway infrastructure intersects with road networks at numerous level crossings. At these locations, trains and road vehicles occupy the same physical corridor at different times. A railway train requires a considerably longer stopping distance than a road vehicle; consequently, preventing unauthorized road traffic from entering the crossing before a train arrives is a fundamental safety requirement.

- Warning lights remain inactive.
- Audible alarms remain inactive.
- Crossing occupancy is monitored.
- System health is continuously checked.

Stage 2 – Train Detection

When a train is detected:

- The controller confirms the detection.
- Train direction is established.
- Warning lights are activated.
- Audible warning is activated.
- Remote monitoring system receives a train-approach event.

Stage 3 – Barrier Closing

After the warning interval:

- The barrier begins to close.
- Barrier-position sensors verify movement.
- The controller checks for an obstruction.
- If the barrier fails to reach its commanded position, a fault is generated.

Stage 4 – Crossing Protection

Once the barrier is closed:

- The system continues monitoring the crossing.
- Obstacle sensors remain active.
- The system monitors train occupancy.
- Any abnormal condition is transmitted to the control centre.

Stage 5 – Train Passage

The system confirms that the train has completely cleared the crossing using the departure detection zone or an approved railway train-detection system.

Stage 6 – Reopening

The barriers are opened only when:

1. The train has cleared the protected section.
2. No unsafe condition is present.
3. The barrier-control system is healthy.
4. Required interlocking conditions are satisfied.

Obstacle Detection

A major enhancement of the proposed system is detection of road users trapped inside the crossing.

Possible sensors include:

Ultrasonic Sensors

Ultrasonic sensors measure distance by transmitting sound waves and measuring their reflection.

Advantages:

- Low cost.
- Simple implementation.
- Suitable for prototype development.

Limitations:

- Environmental sensitivity.
- Limited detection reliability for certain objects.
- Not appropriate as the only safety-critical detection mechanism.

Infrared Sensors

IR sensors can identify the presence of objects within a defined region.

Advantages:

- Low cost.
- Fast response.
- Easy integration.

Limitations:

- Weather and sunlight can affect performance.
- Limited range.
- Possible false detection.

Camera-Based Detection

A camera can provide visual information and can potentially identify:

- Cars.
- Trucks.
- Motorcycles.
- Pedestrians.
- Animals.
- Objects on the track.

AI-based railway obstacle detection is an active research area. Recent work has demonstrated

real-time detection and risk assessment using vision-based models. I  IEEE Xplore+1

Sensor Fusion

The proposed system should use multiple technologies rather than relying on a single sensor.

For example:

Ultrasonic + Radar + Camera

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v

Sensor Fusion

|
v

Obstacle Decision

Sensor fusion can improve reliability because different sensors have different failure modes.

Experimental Methodology

A laboratory prototype can be developed using a scaled railway-crossing model.

Experiment 1 – Train Detection

A model train is moved toward the crossing at different speeds.

Measurements:

- Detection distance.
- Detection time.
- False detections.
- Missed detections.

Experiment 2 – Automatic Gate**Measure:**

- Warning activation time.
- Gate-closing time.
- Gate-opening time.
- Position accuracy.

Experiment 3 – Obstacle Detection

Place different objects inside the crossing:

- Car model.
- Pedestrian model.
- Motorcycle model.

- Cardboard object.

Measure:

- Detection accuracy.
- Response time.
- False-positive rate.

Experiment 4 – Communication

Test remote transmission of:

- Train detection.
- Gate status.
- Obstacle alarm.
- Power failure.
- Sensor failure.

Experiment 5 – Failure Simulation

Intentionally disconnect:

- Sensor.
- Communication module.
- Main power.
- Barrier-position feedback.

The expected result should be that the system transitions to a predefined safe state and reports the fault.

Conclusion

The proposed architecture moves beyond simple automatic gate operation. A reliable railway crossing should detect the train, establish the direction and occupancy of the railway section, warn road users, control barriers, monitor the crossing for trapped objects, verify train departure and continuously report abnormal conditions.

The central principle of the proposed system is therefore automation with fail-safe redundancy rather than automation alone. A properly engineered system can reduce dependence on continuous manpower while improving consistency, monitoring and response. For practical deployment, however, the design must undergo detailed safety analysis, railway-specific engineering, testing, certification and regulatory approval.

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