Development of an Automated Railway Gate Control System for Enhanced Safety in Bangladesh

Md. Misbah Uddin[1], M. I. Washif Rahman[2*], Md. Mostofa Hossain[3], AMM Shamsul Alam[4], Md. Atikur Rahman[5]

[1,2*,3,4,5] Department of Mechanical Engineering, Sonargaon University, Dhaka, Bangladesh.
[*]Corresponding Email: washif.me@gmail.com

Received: April 17, 2025
Revised: June 23, 2025
Accepted: June 30, 2025

Abstract

The railway network in Bangladesh plays a major role in national transportation, economic development, and regional connectivity. But, frequent accidents at level crossings mainly due to manual gate operations pose significant safety concerns. The analysis of accident data of Bangladesh Railway between 2008 and 2022 highlights that human error is a major contributing factor to a large number of accidents. To overcome this issue, this study introduces an Arduino-Based Automatic Railway Gate System (AARS), which firstly detects approaching trains autonomously, then activates the warning signals, and finally controls gate operations without human intervention. The research is structured around four major parts: firstly, an in-depth analysis of accident data Bangladesh railway, to identify the probable causes of railway accidents; secondly, the development and testing of a functional prototype model to demonstrate system feasibility; then, the recommended model for real-time implementation within the existing infrastructure; and finally, a comprehensive estimation of vehicle waiting times at railway crossings, considering both urban and rural areas. The proposed system is designed to reduce accidents, lowering the waiting time of the vehicles at rail crossings, and enhance overall safety. The key contributions of this study are the application of an intelligent control model, a data-driven approach for preventing accidents within a practical framework for implementing these technical concepts into Bangladesh's existing railway infrastructure. This research aims to influence future policy decisions and contribute to the ongoing efforts to modernize railway safety systems, ensuring a safer and more efficient transportation infrastructure.

Keywords: Automatic Railway Gate Control, Railway Level Crossing Safety, Arduino-based Gate System, Ultrasonic Sensor Train Detection, IoT in Railway Automation, Railway Gate Automation in Bangladesh.

1.0 INTRODUCTION


Figure 1: Eleven people including a newly married couple are killed when a Dhaka-bound train rams a microbus in Ullapara on July 15, 2019 (Daily Star, 2025)

A level crossing, also known as a railway crossing, is a location where a railway line intersects a road or pedestrian path at the same points. These crossings are essential for ensuring safe passage across railway tracks but are also among the most vulnerable points in railway infrastructure, especially in developing countries with minimal automation. Bangladesh Railway is a critical part of the national transport system, supporting local and divisional connectivity, trade, tourism, and accessibility throughout the region. But, level crossings safety is still a big concern. Presently, all railway crossing operations in Bangladesh works exclusively on manual control, making the system unsafe due to human error, delayed responses by the gate operator besides an inconsistent gate handling. Accidents at these crossings are frequently caused by operator negligence, poor visibility conditions, defective track components, and the absence of automated safety systems. Statistical evaluation of accident data from the 2008–2022 period shows that almost 33%–39% of level crossing accidents are caused by human error or carelessness, which emphasizes the immediate necessity for a transition from manual to automatic railway gate control systems in railway crossings (Bangladesh Railway, 2022). Although many countries have successfully adopted advanced safety technologies at railway crossings, Bangladesh has yet to introduce such systems.

2.0 LITERATURE REVIEW

Railways play a vital role in transporting people and goods efficiently and are key to many national economies. However, railway-road intersections, or level crossings, pose serious safety risks if not managed effectively (Golder et al., 2023). Accidents at these crossings can cause fatalities, injuries, and service disruptions (Karuppusamy et al., 2025). One major cause of these accidents is the reliance on manually operated gates, which are vulnerable to human error (Chowdhury et al., 2020). Therefore, automating railway gate systems is essential to enhance safety and operational efficiency (Surve et al., 2015; Harshitha et al., 2020).

Automatic railway gate systems use sensors and microcontrollers to detect train movements and operate gates accordingly (Balamurugan et al., 2018). These systems can include features such as obstacle detection, real-time monitoring, and remote operation (Chowdhury et al., 2020; Praiseline et al., 2019). Technologies like infrared (IR) sensors, RFID, GSM, and IoT are commonly used to implement such systems (Balamurugan et al., 2018; Dayana & Bhuvaneshwari, 2019).

IR sensors detect trains by monitoring changes in reflected light, while ultrasonic sensors are used to identify obstacles on the tracks (Reddy et al., 2023; Praveena & Sangeetha, 2020). Arduino microcontrollers and PLCs provide control logic, allowing sensors to activate gate mechanisms reliably (Surve et al., 2015; Kumar & Sachdeva, 2015). GSM modules enable SMS alerts to gatekeepers or train operators about approaching trains or detected hazards (Rohini & Parthasarathi, 2021), while IoT technology allows for remote control and monitoring (Kumar et al., 2019; Kumar, 2016).

The automation of gate operations greatly minimizes human errors and enhances safety at crossings (Khan et al., 2019). Obstacle detection systems help prevent collisions with vehicles or pedestrians trapped on tracks (Yathish & Nandini, 2020). Additionally, automated systems reduce gate closure time, easing road traffic congestion and enhancing vehicle flow (TechRxiv, n.d.). Remote management capabilities also allow operators to monitor system performance from centralized locations (Rohini & Parthasarathi, 2021). In the long term, automation can reduce labor costs and optimize resource allocation (TechRxiv, n.d.).

However, several barriers to implementation exist. The high initial cost of components like sensors, controllers, and communication devices can be a significant obstacle, especially in developing countries like Bangladesh (Kalaivani, 2019; Imran & Won, 2020). Moreover, system performance may be affected by hardware failures, power outages, or network disruptions (Kalaivani, 2019).

Another major concern is cybersecurity. IoT-based systems are susceptible to hacking, which could result in unauthorized control of gates and potentially catastrophic accidents (Televic, 2023). Malicious actors might gain access to systems and alter gate operation, disrupting train schedules and endangering lives (Imran & Won, 2020). Thus, implementing robust cybersecurity measures is essential for safe operations.

Bangladesh, like many other developing countries, still relies on manual gate operations and faces infrastructural limitations (Chowdhury et al., 2020). Limited modernization funding and a lack of trained personnel further compound these challenges (Kalaivani, 2019). In contrast, advanced economies such as Japan, South Korea, and the UK have adopted fully automated train and gate control systems, demonstrating the benefits of modern technology in enhancing railway safety (European Union Agency for Railways, 2024).

The use of ultrasonic sensors continues to gain traction for obstacle detection, and their accuracy has made them a reliable addition to modern gate systems (Surve et al., 2015; Praveena & Sangeetha, 2020). IoT integration allows continuous monitoring and analysis of performance data (Kumar et al., 2019), while remote access provides timely responses to emergencies (Hossen et al., 2022). Sustainability is another emerging focus. Renewable energy sources such as solar and wind power can be used to run these automated systems (Kalaivani, 2019; Ghosh et al., 2021). This makes gate control both cost-effective and environmentally friendly, especially in remote areas where grid power is unreliable.

To ensure operational safety, systems must include redundancy and fail-safe features. Redundant components ensure backup functionality in case of failure, while fail-safe mechanisms default the system to a safe state during malfunctions (Kalaivani, 2019). Moreover, standardized emergency protocols are essential for quick response in the event of an incident (Kumar & Sachdeva, 2015). Compliance with national and international railway safety regulations is also necessary. Adopting standardized systems ensures compatibility and safety across networks (Seredovich, 2023). Additionally, smart city initiatives can integrate railway automation into broader transportation management plans, boosting overall infrastructure intelligence (Stanley Consultants, 2024).

Artificial intelligence (AI) and machine learning (ML) offer further opportunities to enhance these systems. AI can optimize gate operation based on train schedules and track conditions, while ML can improve obstacle detection and reduce false alarms (Oberle, 2020). The future may see fully autonomous railway control systems that ensure maximum safety with minimal human intervention (Seredovich, 2023).

3.0 RAILWAY ACCIDENT DATA ANALYSIS OF BANGLADESH

This section of the paper presents a critical analysis of accident data related to railway incidents in Bangladesh. The data has been gathered from multiple sources, including railway authorities, scholarly articles, and news reports.

Table 01: Railway Accidents Summary of Bangladesh (2008-2022)

Year (July-June)	Accidents due to				Total
	Collisions	Derailments	Fire in trains	Train running into obstruction	No of Accidents
2008-2009	7	408	0	34	449
2009-2010	2	403	0	34	439
2010-2011	1	392	0	18	411
2011-2012	0	138	0	16	154
2012-2013	3	133	0	15	151
2013-2014	1	158	0	18	177
2014-2015	0	292	0	20	312
2015-2016	0	123	0	43	166
2016-2017	2	44	1	33	80
2017-2018	3	78	0	10	91
2018-2019	3	78	0	10	91
2019-2020	1	72	0	7	80
2020-2021	3	92	0	16	111
2021-2022	0	67	0	12	79

Source: Adopted from Bangladesh Railway (2022)

These data reflect railway accidents over a span of 14 years (2008–2022), categorized by cause. Analyzing this chart helps underline the importance of automatic railway gating systems, especially in reducing certain types of accidents. The major findings are

- Derailments are the main cause of accidents, 2,769 out of 3,036 cases (91.2%). While not all are due to level crossings, issues like poor coordination or vehicles stuck on the tracks at unmanned gates can play a role.
- 223 accidents (7.3%) happened when trains hit obstructions. These are largely avoidable with automatic gates that keep tracks clear. In 2008–2009 and 2009–2010, such accidents were 34 per year, showing how risky manual or unguarded gates can be.
- There were 26 train collisions (0.86%). Many were likely caused by signal issues or problems at crossings.

In addition, this following graph highlights a consistent pattern of railway accidents in Bangladesh caused by **collisions** and **trains running into obstructions** from 2008 to 2022. Obstruction-related accidents are significantly higher, peaking in 2015–2016, and reflect the dangers of **manual gate operation and unguarded level crossings**.

Figure 02: Year-wise accidents graph due to collisions and trains running into obstructions.

Of the 7.3% obstruction-related accidents and 0.86% collision accidents (together~8.2%), automatic railway gating systems could directly prevent these, ensuring:

- Gates close automatically before a train approaches.
- Signals alert incoming traffic and pedestrians.
- Integration with centralized systems for better scheduling and real-time alerts.

Although derailments remain the primary concern, a significant 8.2% of all accidents (about 1 in every 12) could potentially be prevented through automated railway gating systems. These systems are crucial for improving safety at crossings, reducing human error, and saving lives, especially in high-traffic or rural areas where manual systems are insufficient.

Table 02: Annual Statistics of Railway-Related Fatalities and Injuries by Category (2008–2022)

Year	Passenger Killed	Passenger Injured	Railway Employees Killed	Railway Employees Injured	Other Persons Killed	Other Persons Injured	Total Killed	Total Injured
2008-2009	1	10	1	25	20	64	22	99
2009-2010	-	-	-	98	11	40	11	138
2010-2011	-	-	7	143	10	17	17	160
2011-2012	-	-	11	94	35	56	46	150
2012-2013	2	-	2	112	38	54	42	166
2013-2014	2	5	5	87	23	63	30	155
2014-2015	9	17	9	76	23	82	41	164
2015-2016	-	-	-	27	9	27	9	54
2016-2017	3	7	-	-	3	7	6	14
2017-2018	12	35	5	5	12	40	29	80
2018-2019	8	35	7	6	15	41	30	82
2019-2020	6	60	20	26	6	38	32	124
2020-2021	3	2	2	26	11	37	16	65
2021-2022	3	17	1	5	13	31	17	53

Source: Adopted from Bangladesh Railway (2022)

The casualty table spanning 2008–2022 reveals a disturbing pattern of fatalities and injuries, with "Other Persons" (i.e., non-passengers and non-railway employees) consistently accounting for a significant share of both deaths and injuries. For example:

- In 2011–2012, 35 other persons were killed and 56 injured.
- In 2014–2015, 23 killed and 82 injured.
- As recently as 2021–2022, 13 were killed and 31 injured in this group alone.

These individuals are often pedestrians, cyclists, or vehicle drivers at unmanned or poorly managed railway crossings-making them especially vulnerable due to manual gate operations, lack of real-time signaling, and limited situational awareness.

This group represents people likely involved in level crossing accidents i.e., pedestrians, drivers, or others on or near railway tracks.

Between 2008–2022:

- An average of ~20–35 people per year were killed or injured in this category.
- This is more than passengers or railway staff combined in some years (e.g., 2011–2013).

Moreover, the overall annual death toll has ranged from 14 to 166, with many injuries resulting from avoidable train-crossing incidents. Fluctuations indicate inconsistent safety practices and infrastructure.

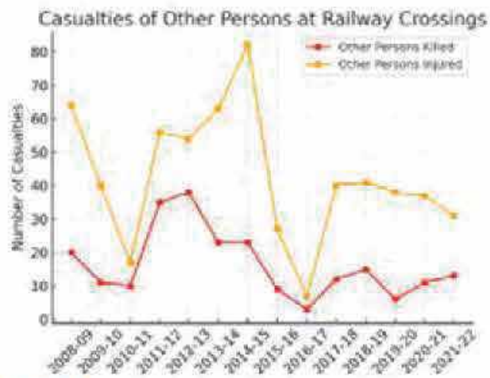

Figure 3: Casualities of other persons at Railway Crossings

Table 03: Different factors involve in railway accidents (2008-2022)

Accident Factors	Detailed Causes	2018-2019	2019-2020	2020-2021	2021-2022
1.Human Elements	1. Breach of Rules, Wrong manipulation of block instruments and setting points etc	38.46%	35%	33%	39%
	2. Passing of signals at danger	1.10%	2.50%	5.13%	8.86%
2.Technical defects	1. Engines	3.30%	3.75%	4.27%	5.06%
	2. Vehicles	2.20%	2.50%	3.42%	5.06%
	3. Signaling and interlocking apparatus and other technical defects.	2.20%	6.25%	7.69%	5.06%
	4. Other technical defects	3.30%	3.75%	4.27%	7.59%
3.Other Causes	1. Miscellaneous	60.40%	46.25%	41.88%	29.11%

Source: Adopted from Bangladesh Railway (2022)

The data clearly shows that human error remains a dominant cause of railway accidents, with “Breach of rules and wrong manipulation” consistently contributing over 33%–39% of accidents annually. Additionally, “Passing signals at danger”-another human-related error-has increased steadily from 1.10% in 2018–2019 to 8.86% in 2021–2022. This trend highlights growing safety risks due to manual operations and delayed human responses.

In contrast, while technical defects and miscellaneous causes fluctuate, the human factor consistently ranks as a major contributor. This emphasizes the urgent need to minimize human involvement in critical operations like railway gate control, where a delayed or incorrect decision can lead to catastrophic outcomes.

4.0 PROPOSED MODEL

The aurdino uno is the main controller of this proposed model as it controls the opening/closing of gates through a servo motor and indicates the signals (LED and Buzzer) to road users. The other components are Ultrasonic sensors, Power Supply, Buzzer, Red and green LED, Breadboard, Jumper Wires, prototype Train, PVC Board etc.

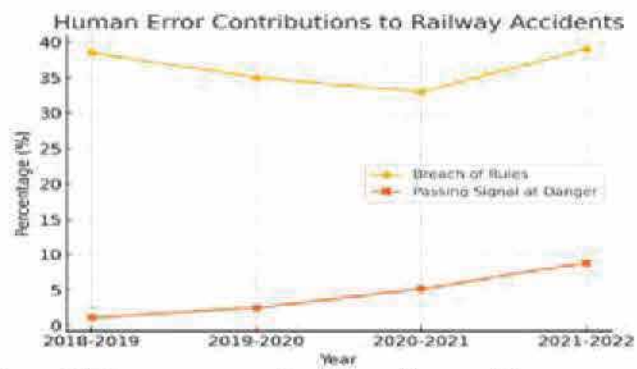

Figure 04: Human error contributions to railway accidents.

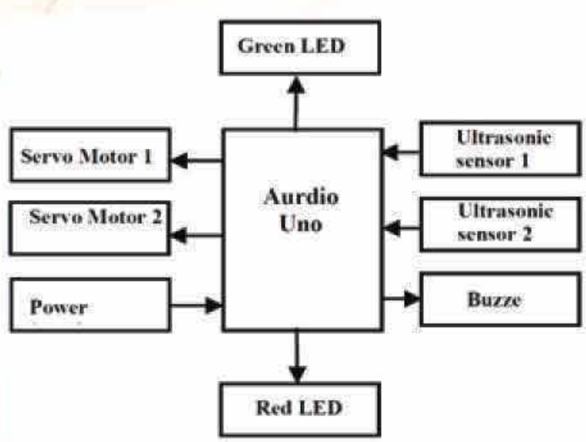

Figure 05: Block diagram of the Proposed Model

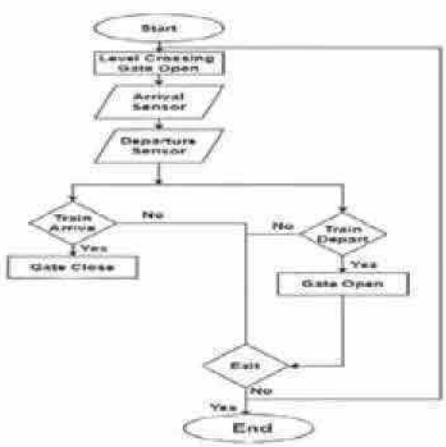

Figure 06: Flow chart of the Proposed Model (Chowdhury et al., 2020)

Rail Presence	Sensor (1st) State	Sensor (2nd) State	Motor Angle	Buzzer State	Traffic light Signal State	Rail gate State
No	Low	Low	No motor rotation	Low	Green	Open
Rail on 1st sensor	High	Low	Motor rotates in CW 0º to 90º	High	Red	Close
Rail on 2nd sensor	Low	High	Motor rotates in CCW 90º to 0º	Low	Green	Open

Figure 07: Experimental setup of the Proposed Model

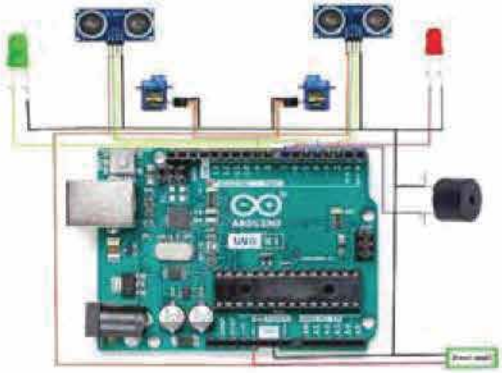

Figure 08: Wiring diagram of the Proposed Model

Both the ultrasonic sensor is place 21cm away from the railway gate. When the 1st Sensor detects the arrival of the train it will send the signal to aurdino uno which activates the servomotor in order to close the gate, the green LED will turn into red and buzzer will ring. On the other hand When the 2nd Sensor detects the departure of the train it will send the signal to aurdino uno which activates the servomotor in order to open the gate, the red LED will turn into green and buzzer will off.

5.0 CALCULATION

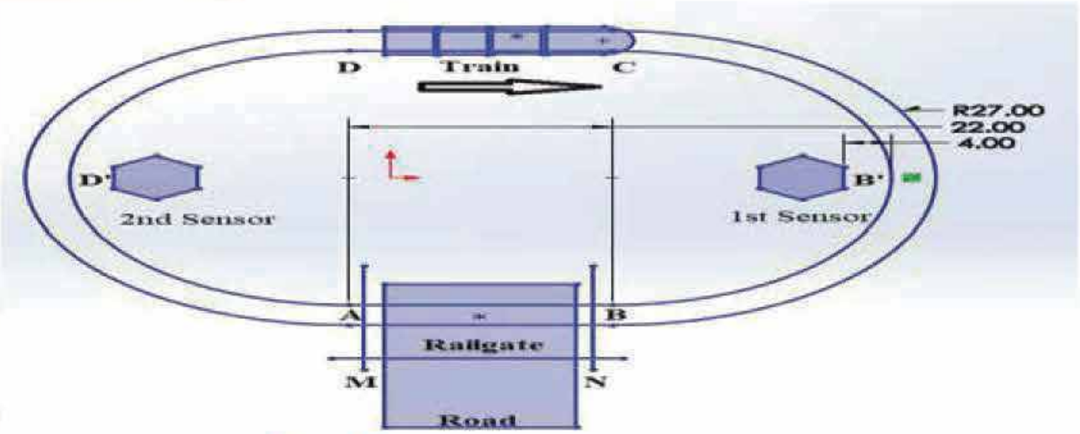

Figure 09: CAD design for experimental setup

Table 04: Several conditions on the train's position

Total Distance of the railway track 'S'

$S_{AB} = 22cm$, $S_{BC} = \pi*(BB`C)/2 = 42.21cm$, $S_{CD} = 22cm$, $S_{DA} = \pi*(AD`D)/2 = 42.21cm$

$S = S_{AB} + S_{BC} + S_{CD} + S_{DA}$
$= 213.64cm \approx 214cm$

Total Time taken,
$T = T_{AB} + T_{BC} + T_{CD} + T_{DA}$
$= 1.3 + 2.7 + 1.3 + 2.7$
$= 8$ sec

Average speed of the train
$V = S/T = 214/8$
$= 26.75cms^{-1}$

Gate closing time
Distance from 1st sensor to the road $B`BN = 45.4cm$
$T_1 = B`BN / V$
$= 45.4/26.75$
$= 1.7$ sec
Gate Opening time :
Distance from 'N' to the 2nd sensor $NAD` = 61.4cm$
$T_2 = NAD` / V$
$= 61.4/26.75$
$= 2.3$ sec
Total Time for Gate Operation:
Total time taken $= T_1 + T_2$
$= 1.7 + 2.3$
$= 4$ sec

Time taken by the sensor to detect the train

Distance between train and sensor, S= 4cm
Speed of ultrasonic wave in air, V= 343 m/s

Time to detect the train by the sensor,
$T = 2S/V = 2X4(100X343)$
$= 233.23$ micro sec

6.0 RESULT AND DISCUSSION

The total distance of the railway track is 214cm. The average velocity of the train is $26.75cms^{-1}$ and it will take 8sec to cross the full railway track. The train will need 4 seconds to travel the 106.8 cm between the first and second sensors and the gate will remain closed for 4 seconds. Besides the sensor's detection time for the train is 233.23 microseconds.

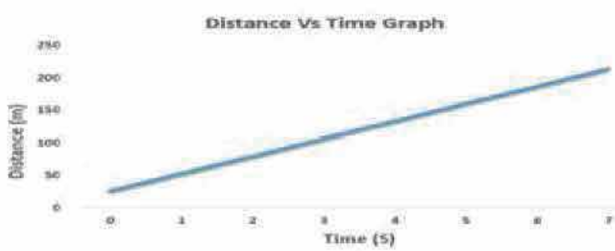

Figure 10: Distance vs. Time of the Train

7.0 RECOMMENDED MODEL FOR REAL LIFE IMPLEMENTATION

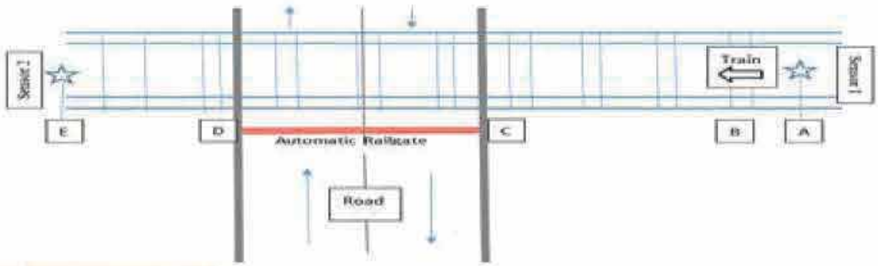

Figure 11: Recommended model

When the train will reach at point A, the 1st sensor will detect the train, the buzzer will ring, and green light will be turned into red. Then when the train reaches at point B, the gate will start to close. At point E, 2nd sensor is placed. When the train reaches point E, the gate will open, the red light will be green, and the buzzer will stop.

*Waiting Time Calculation

Assumptions

i) Train is running inside the city at the constant speed of 20Km/hr .

ii) One way railway track

iii) Train is moving from the point A to the point E

NOTE: For the simplification of the calculation train's length is not considered here. The sensor position and also the waiting time should be adjusted according to the train's length.

S_{ED}=18.3m	S_{DC}=18.3m	S_{CB}=600m	S_{BA}=300m
V= 20Km/hr	V= 20Km/hr	V= 20Km/hr	V= 20Km/hr
=5.5m/s	=5.5m/s	=5.5m/s	=5.5m/s
T_{ED}= S_{ED}/V	T_{DC}= S_{DC}/V	T_{CB}= S_{CB}/V	T_{BA}= S_{BA}/V
= 3.35 ≈ 4sec	= 3.35 ≈ 4sec	= 109.09 ≈ 110sec	= 54.54 ≈ 55sec

In the city model the first sensor should be placed 900m before the rail crossing and 18.3m after the rail crossing. Total waiting time

$T= T_{ED} + T_{DC} + T_{CB} + T_{BA}$

$= 4+4+110+55= 173sec$

Similarly, for the rural region, the train speed is assumed 60Km/hr, and the waiting time has been calculated is 170.9sec ≈171sec. The position of 1st sensor would be 2750m before the rail crossing and 2nd sensor would be 66.68m after the rail crossing.

Table 05: Proposed waiting for the vehicle inside and outside of the

Segment	Distance (m) when Train is Speed 20Km/hr inside the city	Waiting Time (sec)	Distance (m) when Train is Speed 60Km/hr outside the city	Waiting Time (sec)
A-B	300	55	750.15	45
B-C	600	110	2000	120
C-D(Road)	18.28	4	18.28	1.09
D-A	18.28	4	66.28	4
Total Waiting time		**173**		**170.09**

8.0 CONCLUSION

In conclusion, from 2008 to 2022, 249 out of 3,036 recorded railway accidents in Bangladesh (8.2%) could have been prevented with automatic railway gating systems, with 223 obstruction-related and 26 collision incidents. Human error, responsible for over 39% of these accidents, could have been minimized through automation, ensuring faster and more reliable gate operations. The proposed Arduino-based Automatic Railgate System (AARS) detects trains in just 233.23 microseconds, closing the gate within 4 seconds over 106.8 cm. With waiting times calculated at 173 seconds in urban areas and 171 seconds in rural areas, this system enhances safety by reducing delays and minimizing human intervention, addressing the 37.5% of accidents caused by human error in 2019-2020. The implementation of AARS offers a transformative solution for safer and more efficient rail travel in Bangladesh.

9.0 FUTURE SCOPE

The horizon for advancing the Arduino-Based Automatic Railgate System (AARS) is ripe with possibilities. Our future scope encompasses the integration of load sensors for real-time cargo monitoring, advanced IR technology to enhance train detection, and image processing capabilities to improve performance in low-visibility conditions. Furthermore, the incorporation of PLC-based control systems can be enabled precise and efficient gate operations.

In addition, the introduction of GPS functionality will facilitate real-time train tracking and coordination, optimizing railway operations. In addition, the implementation of automatic braking systems will provide a comprehensive approach to railway safety, enhancing emergency response capabilities. The establishment of a centralized control room for monitoring and managing railway crossings will further streamline operations, ensuring swift responses to incidents.

Lastly, the inclusion of stuck detection technology will identify and resolve gate system issues promptly, guaranteeing uninterrupted railway services. These advancements collectively represent an exciting future for AARS, solidifying its position as a cornerstone of innovation within Bangladesh's railway infrastructure, fostering both safety and efficiency.

References

Bangladesh Railway (2022). Bangladesh Railway information book 2022. Chief Planning Officer, Bangladesh Railway.

Chowdhury, K. B. Q., Khan, M. R., & Razzak, Md. A. (2020). Automation of Rail Gate Control with Obstacle Detection and Real Time Tracking in the Development of Bangladesh Railway. 2020 IEEE 8th R10 Humanitarian Technology Conference (R10-HTC), 1–6. https://doi.org/10.1109/R10-HTC49770.2020.9356986

Daily Star. (2025). 10 killed as train hits microbus. The Daily Star. Retrieved May 1, 2025, from https://www.thedailystar.net/frontpage/news/10-killed-train-hits-microbus-1772011

European Union Agency for Railways. (2024). European Train Control System (ETCS) deployment and safety enhancements. Retrieved from https://www.era.europa.eu/activities/european-train-control-system_en

Ghosh, S., Alam, M. N., Das, N., & Uzzaman, I. (2021). Solar power driven automatic railway crossing system with obstacle detector to prevent accidents in Bangladesh. ResearchGate. Retrieved from https://www.researchgate.net/publication/369693345_Solar_Power_Driven_Automatic_Railway_Crossing_System_with_Obstacle_Detector_to_Prevent_Accidents_in_Bangladesh

Golder, A., Gupta, D., Roy, S., Al Ahasan, Md. A., & Haque, M. A. (2023). Automated Railway Crossing System: A Secure and Resilient Approach. 2023 IEEE 14th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), 0247–0253. https://doi.org/10.1109/uemcon59035.2023.10315973

Harshitha D., Monika N., Kavya N. R., & Mounika B. (2020). Automatic railway gate control system. International Journal of Progressive Research in Science and Engineering, 1(3), 86–88. Retrieved from https://journal.ijprse.com/index.php/ijprse/article/view/55

Harshitha, D., Monika, N., Kavya, N. R., & Mounika, B. (2020). Automatic railway gate control system. International Journal of Progressive Research in Science and Engineering, 1(3), 86–88. https://journal.ijprse.com/index.php/ijprse/article/view/55

Hossen, E., Ayman, U., Uddin, M. K., Ferdous, K. A., & Deowan, M. E. (2022). Smart railway gate control system using Internet of Things (IoT). ResearchGate. Retrieved from https://www.researchgate.net/publication/362173596_SMART_RAILWAY_GATE_CONTROL_SYSTEM_USING_INTERNET_OF_THINGS_IOT

Imran, N. M., & Won, M. (2020). Reducing operation cost of LPWAN roadside sensors using cross technology communication. arXiv preprint arXiv:2009.12471. https://arxiv.org/abs/2009.12471

Karuppusamy, P., Subiksha, A., Gayathri, J., Dhanush, A., & Kavin, S. (2025). Automatic Railway Gate Crossing Control And Track Crack Detection System Using IoT. 2025 6th International Conference on Mobile Computing and Sustainable Informatics (ICMCSI), 362–367. https://doi.org/10.1109/ICMCSI64620.2025.10883595

Kumar, R. (2016). Simulation and potential for Indian Railways - IRTPMS. Indian Railways Technology Platform Management System. Retrieved from https://irtpms.in/front/uploads/reports/20.Simulation-Potential-for-Indian-Railways-Rajnish-Kumar.pdf

Oberle, K. (2020, November 12). Improving rail crossing safety with artificial intelligence. Global Railway Review. Retrieved from https://www.globalrailwayreview.com/article/109855/improving-rail-crossing-safety-artificial-intelligence/

Reddy, S. S. R., Reddy, S. R., & Reddy, P. S. R. (2023). Sensor-based automatic control of railway gates. Rajeev Gandhi Memorial College of Engineering and Technology. Retrieved from https://www.rgmcet.edu.in/NAAC/2023/1.3.3/Project%20Reports/2019-20-Projects/2019-20-CE-SENSOR%20BASED%20AUTOMATIC%20CONTROL%20-5.pdf

Ristić-Durrant, D., Franke, M., & Michels, K. (2021). A review of vision-based on-board obstacle detection and distance estimation in railways. Sensors, 21(10), 3452. https://doi.org/10.3390/s21103452

Rohini, D., & Parthasarathi, N. (2021). Automatic railway gate control alerts via SMS. Perspectives in Communication, Embedded-Systems and Signal-Processing (PiCES), 5(4), 52–53. https://doi.org/10.5281/zenodo.5472183

Seredovich, J. (2023, October 12). Railway predictive maintenance: Assessing best practices using IoT. O2 Inc. Retrieved from https://o2inc.net/railway-predictive-maintenance-assessing-best-practices-using-iot/O2 Technologies

Sivakumar, S., & Sangeetha, R. (2023). Automatic railway gate level control system. Heritage Research Journal, 71(4), 17–19. Retrieved from https://heritageresearchjournal.com/wp-content/uploads/2023/07/HRJ-R1444.pdf

Stanley Consultants. (2024, July 29). The synergy of intelligent transportation systems and integrated infrastructure in smart cities. Retrieved from https://www.stanleyconsultants.com/solutions/engineering-design/blog/the-synergy-of-intelligent-transportation-systems-and-integrated-infrastructure-in-smart-cities

TechRxiv. (n.d.). Automated Railway Crossing System. Retrieved from https://www.techrxiv.org/users/692761/articles/682732/master/file/data/Rail_Crossing_Syatem/Rail_Crossing_Syatem.pdf

Televic. (2023). Advanced cybersecurity tactics for train operators. Retrieved from https://www.televic.com/en/rail/articles/advanced-cybersecurity-tactics-for-train-operators

Yathish, D. P., & Nandini, S. (2020). Prevention of disasters using automated railway crossing system. International Journal of Engineering and Advanced Technology (IJEAT), 9(4), 492–495. https://doi.org/10.35940/ijeat.D7018.049420