Enhancing Animal Safety Measures by Avoiding Train Collisions Using Internet of Things (IoT) with Advanced Sensors Association

S. Praveen Kumar, S. Kaviraj, R. Naveen Kumar and T. Nagaarjunan
Department of Computer Science and Engineering, Mahendra Engineering College, Tamil Nadu, India

Keywords: Animal Safety, Train Collision, Internet of Things, Accident Avoidance, IoT, Sensor, Train Accidents, Wildlife Safety.

Abstract: Transportation infrastructure degrades ecosystems in part because animal deaths caused by car accidents disrupt ecosystem dynamics and endanger vulnerable species. Despite the prevalence of wildlife train crashes globally, this issue has received comparatively less attention in the realm of railroads compared to highways, where it has been well studied and mitigated. The Naxalites in India will likely try to derail our protest train by releasing tracks, and the Indian railways might be in danger from an animal-rail collision in a forested region. Currently, behind China, Russia, and the US, India's railway network management ranks fourth globally. India is a good case in point; in the last five years, the Indian government has enacted a plethora of legislation meant to safeguard wildlife sanctuaries and jungle creatures living in close proximity to railway tracks. Our analysis of crack detection and animal-rail collisions in the surrounding region will help us figure out how to fix this issue and whether or not these problems might drive up the budget for the Indian Railways and cause casualties and damage to property. In this paper, we present a cost-effective solution to the problem of managing rail-animal accidents. We propose using load cells to receive the precise location of the defective area in the track, which will help with both the protection of animals and other living beings from being run over by trains and the monitoring of the track's integrity. Many lives can be spared if the affected area is promptly corrected.

1 INTRODUCTION

Complex interactions between transportation networks and wild animals are well-documented (Seiler A, et al., 2017). Numerous species see a decline in population near roadways, which has the ability to change community make-up and ecological processes due to habitat loss, fragmentation, degradation, and direct death. Some species thrive in the areas immediately next to the roadway, while other species are attracted to those areas despite the high mortality rate, suggesting that roadways do not carry a universally negative impact on wildlife. Because railroads are less ubiquitous than highways, or possibly because they offer lower risk to humans, strikes on trains have attracted less attention than strikes on roadways. However, there is evidence that train strikes can have an impact on populations, and animals are occasionally hit more frequently by trains than by roads nearby. Rail workers are much more motivated to reduce strikes if the populations they serve are vulnerable or endangered, or if the species they represent is charismatic, keystone, or socially significant (N.Selvakumar, et al., 2020),(Irene Nandutu, et al., 2022),(Surbhi Gupta, et al., 2021). On railroads, the most effective strategies for lowering the number of wildlife-vehicle accidents never work. In order to decrease the incidence of wildlife-vehicle accidents by as much as 80% while still allowing ecosystem connection, wildlife exclusion fences and crossing structures are being used more and more. Although animals killed by automobiles have consumptive, passive-use, and management values, these road mitigation measures are expensive. There may be a better use of resources on trains, since strikes seldom harm humans. In areas where rail traffic is much lighter than on regular roads, it may not be essential to exclude animals from advantageous foraging, travelling, and living options along trains by erecting exclusion fence. Alternatives to exclusion fence include warning signs or animal detection systems that increase driver awareness, which can help them slow down in the event that they see an animal, thereby avoiding a collision with

Kumar, S. P., Kaviraj, S., Kumar, R. N. and Nagaarjunan, T.
Enhancing Animal Safety Measures by Avoiding Train Collisions Using Internet of Things (IoT) with Advanced Sensors Association.
DOI: 10.5220/0013871300004919

In *Proceedings of the 1st International Conference on Research and Development in Information, Communication, and Computing Technologies (ICRDICCT'25 2025) - Volume 1*, pages 680-687
ISBN: 978-989-758-777-1

wildlife. The opposite is true for train operators, who need minutes of notice time to safely slow down and cannot alter their path. Road and rail accidents involving animals are likely lessened by reducing speeds systematically, which leads to shorter stopping distances. Animals may run off of the trail if they are fleeing from thick snow, steep terrain, or bodies of water; these actions nullify the effect of reduced speed unless it is reduced severely (Gayathri K K, et al., 2023), (S.R. Mathu sudhanan, et al., 2025), (Shanaka Gunasekara, et al.,2021).

Another way to lessen the likelihood of wildlife-train incidents is to make it more likely that animals will get off the track when they see a train coming. Animals and humans alike are at risk of direct collision or an abnormal flight response, maybe brought on by fear, if they are unable to recognize an approaching train. Elements such as vegetation, terrain, heavy snow, particularly along track deviations, or competing stimuli from neighboring rivers or roads may have a large impact on the visibility and audibility of an approaching train and, thus, increase the likelihood of these detection failures occurring. It is reasonable to presume increased accident risk exists whenever these factors are present at locations that the animals actively frequent. Certain scenarios may benefit from the given a warning signal, one that could not be covered or disguised, in advance of train arrival to lessen the likelihood of detection failures. If the signals were delivered at a steady success time clocked relative to the train's arrival, and whether stimuli providing warning signals or conditions related to train arrival are different, animals could learn to associate warning stimuli in advance of train arrival (Shizhong Zhao, et al.,2024). The signal does not have to be aversive, as ignition near the conveyance in motion is an aversive unconditioned stimulus. A wildlife caution system recently utilized these behavioral principles in similar fashion to human road-railway crossing lights. These systems are effective, but they are costly and proprietary, and they need tight interaction with railway infrastructure. Roadside wildlife warning systems, including deer whistles and headlight reflectors, that are less expensive, are mostly useless. The reason behind this might be because when a vehicle is close by, reflectors and whistles fail to offer the same level of spatial and temporal accuracy as conditioned warning cues (Julia Milewicz, et al., 2021), (ISTIAK MAHMUD, et al.,2023). We detail an electronic system that integrates the active warning system's pinpoint signaling with the passive warning system's adaptability to different installations and low cost in order to lessen the frequency of wildlife-train accidents.

2 RELATED WORKS

There has been a steady rise in the number of vehicle accidents resulting in injuries and fatalities to both humans and animals throughout the globe (Atri Saxena, et al.,2020). Therefore, AVCs, which include wildlife species, pose a serious risk to road safety. For road safety and wildlife conservation, it is necessary to implement a mitigation strategy that will decrease the frequency of vehicle-wildlife accidents. An innovative approach for detecting animals and avoiding collisions utilizing object detection is presented in this research. For animal detection, the suggested approach considers neural network architectures such as SSD and the quicker R-CNN. This study creates a new dataset with 31,774 photos from 25 different animal groups. After that, a model for animal detection is created using SSD and quicker R-CNN object detection. Mean average precision (mAP) and detection speed are the metrics used to compare the new method's performance to that of the current one. Using faster R-CNN and an SSD, the suggested technique achieves a detection speed of 82.11% at 10 fps and a mAP of 80.5% at 100 fps.

Wildlife populations are further threatened from tragic animal incidents on railroads (Balaji Kannan, et al.,2024). Official figures suggest, on average, twenty elephants a year die from train accidents across the nation. Likewise, railroad organizations are conducting the research required to find the causes and prevention methods of these occurrences. Regardless, many incidents are occurring on the railroad lines, most of them near woodland regions. A well-defined technical system is required to warn animals to stay away from the railroad lines in order to lessen the number of wildlife fatalities caused by these hazards. Using Machine Learning (ML) frameworks, this research finds ways to alert both the animals and the loco pilot as they approach railway rails.

Nearly 190 elephants have perished as a result of train collisions in India during the previous 20 years, according to a study by the Ministry of Environment, Forest, and Climate Change (Kandikonda S V S K Devi Prakash, et al.,2023). As noted by Indian Express, from April 2019 to March 2020, trains supposedly ran over considerable amounts of animals. Trains operating below capacity killed 2700 cattle from 2020-2021. According to multiple sources, the loss of livestock has slowed down a large amount of rail journeys. Using a railway line tracking system is proposed in this study as a means to lessen animal mortality. Protecting animals from harm in the event of a train crash is the driving force behind this study's development of a system for object movement detection. Ultrasonic and proximity sensors are used to detect the object's motion. The impending train is alerted to by the loco-pilot and the centralized system by means of an ultrasonic sensor, which also activates a bell. As a result, it keeps animals safe and helps them survive. Rails are considered to be around 5 kilometers from the accident site when the system is triggered. If not, they do nothing.

Among the main cities in the world, railways are the most popular and the most widely used mode of transit (Madhupriya, et al.,2024). The proposed study discusses self-reliant and IoT-based real-time monitoring and control. The Internet of Things has the ability to improve aspects of the railway system. Automating railways can significantly reduce accidents and bring the technology up to date for antiquated legacy systems. We have tested and improved the proposed methods of human and animal identification. Automate the monitoring of many railway-related metrics and provide real-time control. Create an automated system that uses less human effort while preserving energy.

Rail operations and passenger safety are jeopardized in the event of a wildlife-train accident (WTC), especially with big creatures. To assess the most perilous WTC sites and their dispersion, we investigated 1,909 WTCs that took place in the Czech Republic from 2011-2019 (this study (Vojtěch Nezval, et al.,2020)). The 208 WTC hotspots were identified using the KDE technique. They represented 0.7% of the length of the Czech rail network, and contained 782 accidents (41.2%). By using a collective risk metric, we located and ranked the WTC hotspots. More WTCs per unit area occurred near forests or streams than in other locations on the Czech rail network, and fewer along agricultural, urban and industrial land use. Moreover, as most WTCs occurred in less than 1% of the train network, these results could inform placement of crash safety intervention.

3 METHODOLOGY

An approach to animal accident prevention that makes use of load cells and the Internet of Things (IoT) and Arduino UNO is the central component. The train's speed will be reduced and it will stop moving until an object in its path is identified by the load cell microcontroller. When the sensor senses that there is no obstacle in its route, the controller will stop regulating the brakes. The data is instantly visible on the screen and may also be sent to the designated individual via the IoT Module.

(a) Power Supply: A transformer is used to reduce the alternating current (ac) voltage from its normal 220V rms level to the level of the required direct current (dc) output. The full-wave rectified voltage is first filtered using a simple capacitor filter to create a direct current voltage, and then it is supplied by a diode rectifier. Ripple or ac voltage volatility is a common feature of the resultant dc voltage. Regulator circuits eliminate ripples and maintain a constant direct current value regardless of variations in the input voltage or the load linked to the output voltage. One of the common voltage regulator integrated circuits (ICs) is typically used to provide this voltage control.

(b) Transformer: From a voltage range of 0-230V, the potential transformer will reduce it to a range of 0-6V. The next step is to link the potential transformer's secondary to the op-amp-built precision rectifier. Using a precision rectifier has several benefits, one of which is that it produces DC output at the peak voltage, while other circuits simply produce RMS output.

(c) Bridge Rectifier: A bridge rectifier is a circuit that uses four diodes in series. The two corners of the network that are diagonally opposite to each other receive the input to the circuit, while the other two corners provide the output.

(d) IC Voltage Regulators: A voltage regulator is an example of a common integrated circuit. The circuits which comprise a regulator embody a source of reference and a comparator amplifier in addition to being a control device and an overload protector. IC devices can regulate an adjustable voltage, a constant negative voltage, or both. The regulators have power ratings from milliwatt to tens of watts, and load currents in the hundreds of milliampere and tens of amperes are compatible with these values. The following figure 1 shows the block diagram of the proposed system.

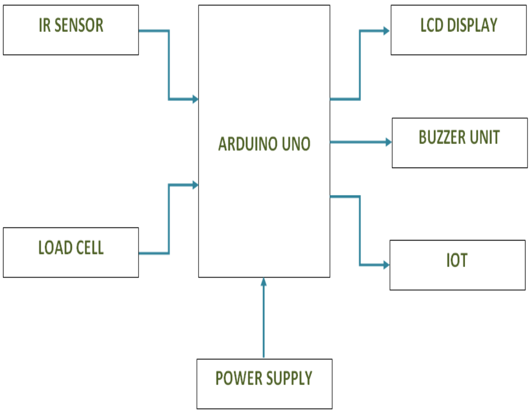

Figure 1: Block diagram.

(i) Arudino UNO: One board that uses the ATmega328 microcontroller is the Arduino Uno. It features a 16 MHz crystal oscillator, six analogue inputs, fourteen digital I/O pins (six of which may be used as PWM outputs), a power connector, an ICSP header, a reset button, and a USB connection. It comes with all the necessary components to support the microcontroller; all you need is a USB cable, an AC-to-DC adapter, or a battery to begin. The following figure 2 shows the Arduino UNO.

Figure 2: Arduino UNO.

(ii) NodeMCU ESP32 IoT Module: The computational power and inbuilt WiFi and Bluetooth connectivity of ESP32 NodeMCU are making them increasingly popular for use in making linked products. Thanks to its breadboard-compatible architecture and ease of programming in the Arduino IDE, the NodeMCU-ESP32 makes comfortable prototyping a reality. With this board, you get a BT wireless connection in addition to 2.4 GHz dual-mode WiFi. The following figure 3 shows the NodeMCU ESP32 IoT Module.

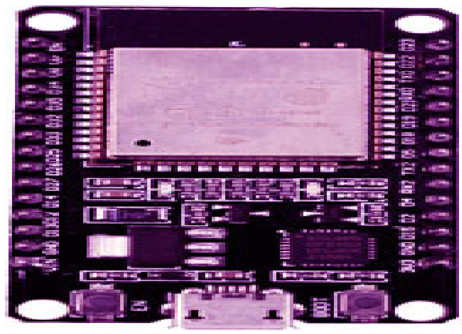

Figure 3: NodeMCU ESP32 IoT module.

(iii) IR Sensor: Electronic devices that generate light in order to detect certain environmental factors are known as infrared sensors. Infrared (IR) sensors can detect motion and also monitor an object's temperature. In contrast to active IR sensors, which generate infrared light, passive IR sensors only detect the presence of infrared light. Every item typically emits some kind of heat radiation in the infrared range. An infrared sensor may pick up on these forms of radiation that aren't visible to the human eye. An infrared light-emitting diode (LED) serves as the source of light, while a photodiode, which is sensitive to infrared light of the same wavelength, acts as the detector. These output voltages and the resistances fluctuate in direct proportion to the intensity of the infrared light that hits the photodiode. The following figure 4 shows the IR Sensor.

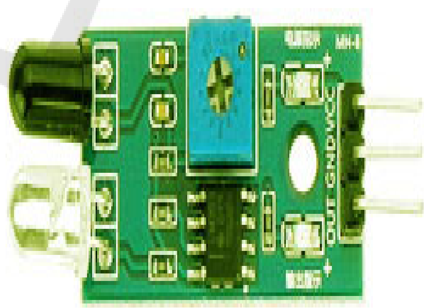

Figure 4: IR Sensor.

(iv) Buzzer Unit: Buzzers and beepers are electrical signaling devices that are often seen in vehicles, home appliances (such microwave ovens), and game shows. Typically, it's made up of a number of switches or sensors that are linked to a control unit. This unit then determines if a certain button was pressed or if a certain amount of time has passed. In most cases, it lights up the corresponding button or control panel and makes a constantly beeping or intermittent buzzing noise as a warning. An electromechanical system, similar to an electric bell but lacking the metal gong (the source of the ringing sound), was the original basis of this apparatus. These devices would frequently be fastened to the ceiling or wall and would utilize them as a kind of soundproofing. The first electromechanical buzzers, which were powered by stepped-down AC line voltage at 50 or 60 cycles, gave rise to the name "buzzer" due to the rasping sound they produced. The usage of a ring or beep is another typical method of signaling the pressing of a button. The following figure 5 shows the buzzer unit.

Figure 5: Buzzer unit.

4 RESULTS AND DISCUSSIONS

Using deep learning neural networks, an IoT-based surveillance system was created to identify animals on railway lines. Cameras and sensors in this system gather real-time data that is analyzed to find animals on the rails. Alerts are given to train operators upon detection, hence allowing quick intervention to stop collisions. Another method uses image processing to find hazards-especially animals-on train tracks using an AI-powered early warning system. The technology notifies trains via IoT apps and Bluetooth transmitters and uses machine learning algorithms to find animals. A buzzer notice warns the train driver to slow down or halt upon detection, hence lowering the possibility of crashes. Using the learning algorithm for object recognition, an Artificial Intelligence (AI) I and IoT based train collision avoidance system captures real-time photos of railway tracks with cameras. The technology emails notifications to authorities, triggers a buzzer to notify the train driver, and shows real-time updates on an LCD screen, so guaranteeing prompt intervention to stop crashes upon finding an obstruction, such as an animal. Using image processing technology, a smart siren system finds animals close to train tracks. Cameras record photographs of the surrounding region; computer vision algorithms then analyze them to find animals. The technology activates a siren to warn animals of an approaching train, therefore motivating them to leave the tracks and so lowering the risk of accidents.

AI-based technologies have been used in India to shield elephants from rail accidents. These gadgets employ movement patterns and infrared imaging to identify elephants using sensor technology. Alerts are transmitted to railway and forest agencies as elephants are discovered, so allowing train conductors to halt or slow down and so avoid accidents. Likewise, Norway has used IoT technology to safeguard reindeer against rail accidents. The technology alerts train operators when they are nearing the reindeer by comparing geo-fence regions with GPS data from reindeer collars, so enabling them to take required measures. By use of IoT and artificial intelligence technology, these systems and implementations show how well they may prevent train-animal collisions, hence improving safety for railway operations as well as wildlife. These systems and studies show how well combining IoT and artificial intelligence technologies prevents train-animal collisions, therefore improving safety for railway operations as well as wildlife. The proposed website design's welcome home page outcome is depicted in the accompanying image, Figure 6.

Figure 6: Welcome message.

Figures 7 and 8 show the suggested hardware unit design and the findings of the animal detection status display clearly, illustrating the proposed technique.

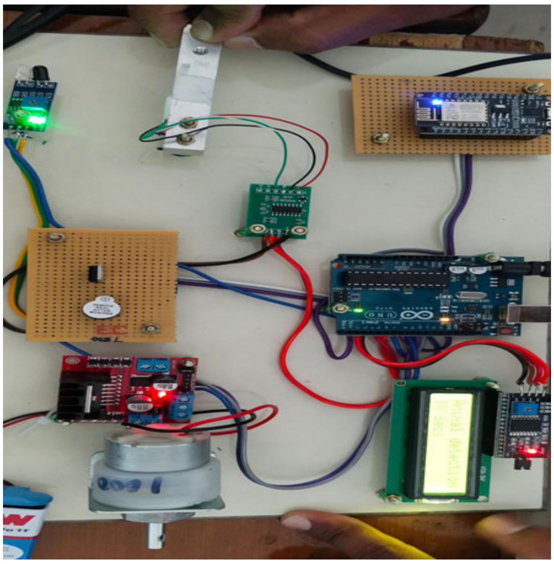

Figure 7: Animal detection.

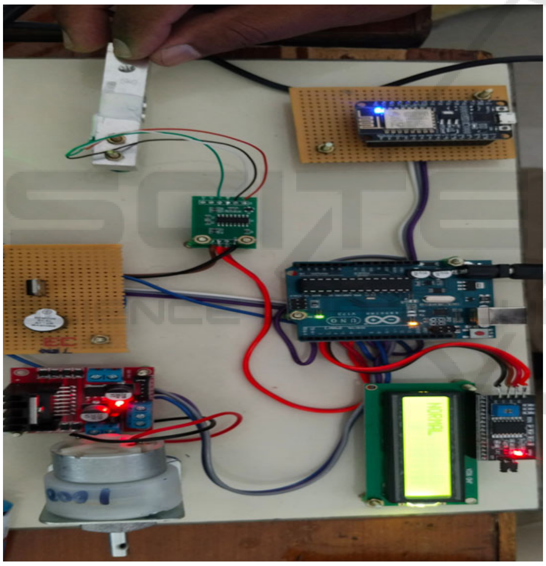

Figure 8: Proposed hardware unit.

The results of the suggested method's crack detection status display and the emergency alarm message raised by IoT web interface are clearly shown in Figures 9 and 10, respectively.

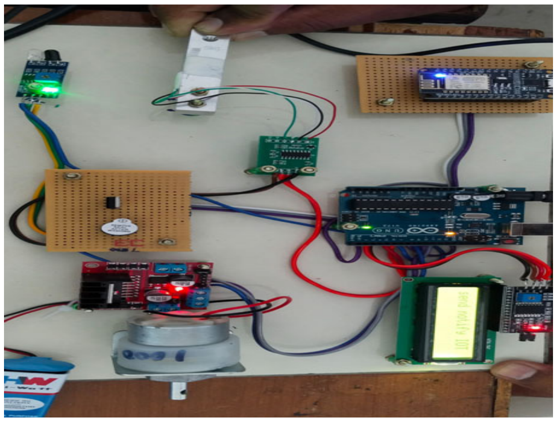

Figure 9: IoT emergency alert notification.

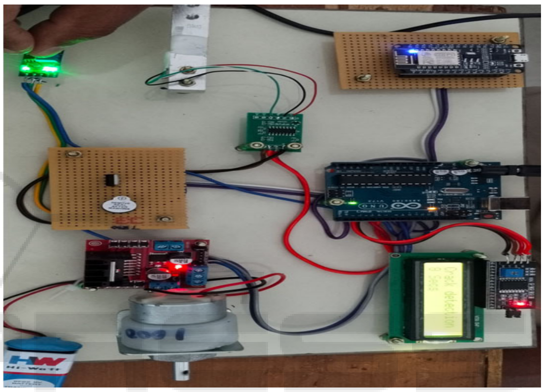

Figure 10: Crack detection.

Figure 11 shows the results of a cross-validation between the suggested method, which makes use of an ESP32 IoT enabled module, and the standard design, which relies solely on an Arduino UNO controller. Table 1 provides a descriptive representation of the same.

Table 1: Analysis of Detection Accuracy Between Proposed Esp32 Module and Normal Arduino Uno Based Design.

S.No.	Days	Arduino UNO (%)	ESP32 (%)
1.	5	87.26	97.94
2.	7	85.54	97.14
3.	10	84.39	97.41
4.	14	87.72	97.38
5.	15	89.29	98.54
6.	18	86.51	98.59
7.	27	84.73	98.47
8.	29	85.95	98.63
9.	33	86.18	97.52
10.	36	84.40	98.29

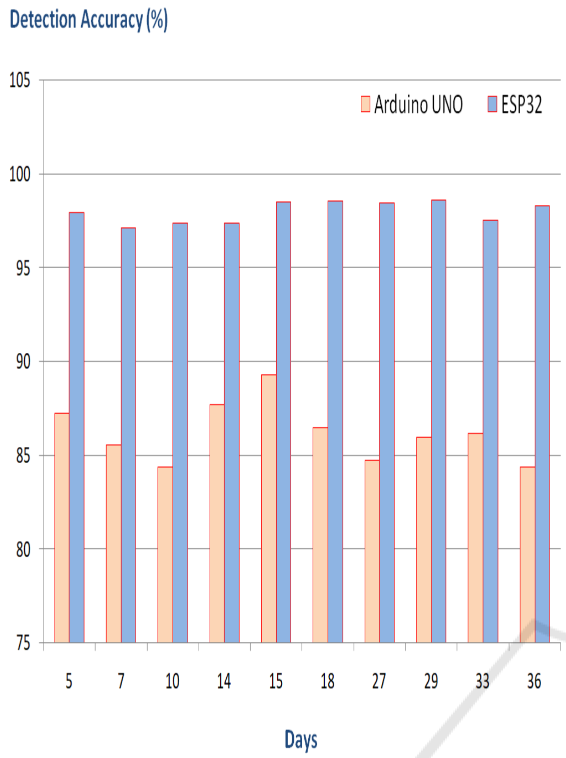

Figure 11: Detection accuracy.

Figure 12 shows the data loss ratio comparison between the suggested method ESP32 IoT enabled module and the standard design, which relies solely on an Arduino UNO controller. Table-2 provides a descriptive representation of the same.

Table 2: Loss ratio comparison between proposed ESP32 module and normal Arduino UNO based design.

S.No.	Days	Arduino UNO	ESP32
1.	5	8.54	1.39
2.	7	9.36	2.16
3.	10	11.52	2.54
4.	14	13.86	2.89
5.	15	15.26	3.24
6.	18	17.69	3.78
7.	27	19.14	3.99
8.	29	22.36	4.16
9.	33	26.34	4.53
10.	36	28.52	4.61

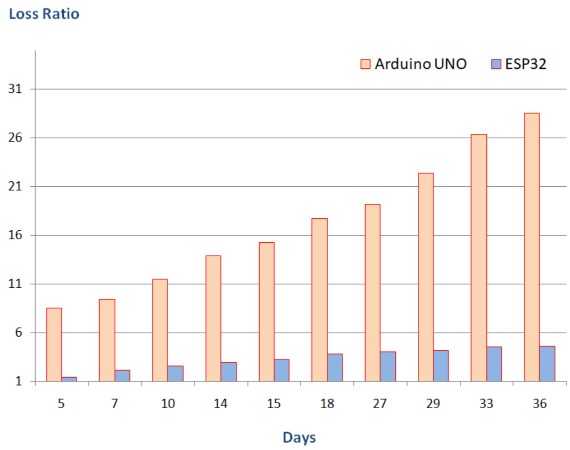

Figure 12: Loss ratio analysis.

5 CONCLUSIONS

To improve railway safety and protect wildlife, it may be necessary to install warning systems that are activated when trains encounter certain animals. Load cells, internet of things (IoT) sensors, and automation based on the Arduino platform work together to make this system capable of detecting obstacles on railway lines and reacting accordingly by notifying authorities and reducing train speeds. By combining infrared sensors with LCD monitors, we can monitor in real-time and respond quickly to avoid mishaps. Reducing the financial burden and animal casualties caused by train-wildlife incidents, this novel solution improves railway operations while also harmonizing with environmental preservation initiatives. Train travel will become safer and more environmentally friendly as new technologies allow for additional iterations of this system. Worldwide, transportation networks pose a threat to both humans and animals. This paper proposes a novel solution.

REFERENCES

Atri Saxena, et al., "An Animal Detection and Collision Avoidance System Using Deep Learning", Lecture Notes in Electrical Engineering, 2020.

Balaji Kannan, et al., "Artificial Intelligence based System to Prevent Animal Accidents in the Railway Tracks", 8th International Conference on Inventive Systems and Control, 2024.

Gayathri K K, et al., "Early Warning System to Prevent Animal-Train Collision", International Journal of Scientific Research in Science and Technology, 2023.

Irene Nandutu, et al., "Intelligent Systems Using Sensors and/or Machine Learning to Mitigate Wildlife–Vehicle Collisions: A Review, Challenges, and New Perspectives", Sensors, 2022.
ISTIAK MAHMUD, et al., "Advancing Wildlife Protection: Mask R-CNN for Rail Track Identification and Unwanted Object Detection", IEEE Access, 2023.
Julia Milewicz, et al., "Methods to reduce wildlife collisions with rail vehicles", Rail Vehicles, 2021.
Kandikonda S V S K Devi Prakash, et al., "Arduino-based Railway Line Tracking System for Mitigating Animal Accidents", International Conference on Computing Methodologies and Communication, 2023.
Madhupriya, et al., "Detection and Accident Prevention of Animals in Railway Track using AI and IoT", International Journal for Multidisciplinary Research, 2024.
N.Selvakumar, et al., "Wildlife and Train Collision Detection System by Wsn", International Journal of Advances in Engineering and Management, 2020.
S.R. Mathu sudhanan, et al., "Using Mask R-CNN and distance transform to detect elephants on railway tracks for collision prevention", Measurement, 2025.
Seiler A, et al., "Wildlife Deterrent Methods for Railways-An Experimental Study", Springer, 2017.
Shanaka Gunasekara, et al., "A Convolutional Neural Network Based Early Warning System to Prevent Elephant-Train Collisions", IEEE 16th International Conference on Industrial and Information Systems, 2021.
Shizhong Zhao, et al., "Passive Safety Assessment of Railroad Trains in Moose Herd Collision Scenarios", Sustainability, 2024.
Surbhi Gupta, et al., "Deep Vision Based Surveillance System to Prevent Train-Elephant Collisions", Research Square, 2021.
Vojtěch Nezval, et al., "Spatial analysis of wildlife-train collisions on the Czech rail network", Applied Geography, 2020.