Automated Detection of Hazardous Areas in Railway Stabling Depots Utilizing Passive Infrared Motion Sensors

Chrzthemmarcdickins B. Bacat[1], John Bryan L. Bulan[2], Jan Marty A. Cantero[3], Ivann Dexter C. Lampano[4], Connie C. Aunario[5], Carlo Jay G. Delizo[6], Sherlie D. Bunag[7], Venerando A. Sison[8], Julius G. Garcia[9]

[1-9] *Technological University of the Philippines, Ayala Blvd., Ermita, Manila, Philippines*

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Correspondence Email:
chrzsthemmarcdickins.bacat@tup.edu.ph

Abstract
This research project aims to construct a motion sensor indication of hazardous railway depot areas to improve the safety of the crew. The project proposes a localized, solar-powered safety system that will govern the inherent dangers of railway station operations and avert possible accidents. The focus was developing and building a prototype incorporating motion sensor technology that uses visual and audio alerts to alert staff of impending dangers in real-time. This method would therefore design a system that consisted of a Passive Infrared (PIR) motion sensor, a siren alarm, a Light Emitting Diode (LED) indicator, and a manual push button that could activate the alarm, along with a Closed-Circuit Television (CCTV) camera for surveillance purposes and a wireless monitor to improve visibility. The prototype was seen to operate correctly in the experiment, where the motion sensor PIR easily sensed any movement and activated the siren alarm and the LED lights. The CCTV camera plus the wireless monitor supplemented and increased surveillance and visibility factors in the danger zone of safety. In this, this research provides a means of significant enhancement in terms of railway station safety that is through using a locally powered, solar motion sensor activation. The real-time detection and alarm of the system can potentially inform staff of potential dangers in time, thereby preventing accidents and creating a safer environment. Further research should be conducted to upgrade the capabilities and usability in different railway depot scenarios. This may involve evaluating different motion sensors, including additional safety devices, and making field tests to evaluate the system's effectiveness in real application cases.

1. Introduction

In the present world, trains are the most dominant form of passenger transportation worldwide. The industry has been constantly developing in all countries. The railway is a desirable means of transport, with an enormous design, prominent features, and phenomena. Many countries have built high-speed rail networks in

Europe and Asia. The United States, however, has the largest rail network in the world. Furthermore, of course, Japan has its bullet train.

Just like these countries are continuously innovating their railroads, the depots play a vital role in storing equipment, maintaining commodities, and making them ready for dispatch for service.

What is a railway depot? Are railway depots different from each other? What is the importance of the railway depot in ensuring staff safety?

A railway depot, sometimes called a train yard or maintenance facility, is designated for storing, repairing, and maintaining trains. Train depots are often situated far from densely populated regions. Depots are important for storing and maintaining trains, ensuring that they operate safely and dependably. It has many amenities designed for complex operating regions that are important to maintain the conditions of the trains, guarantee operational efficiency, and reduce the time spent on downtime. Depots may vary depending on the geographical location and needs of a country. Styles and features may vary based on the individual needs of passengers and commuters.

At the same time, the train depot has a dangerous area where "motion sensor safety indicators" are necessary to ensure staff safety. Traditionally, incidents in these areas have been attributed to human errors, unauthorized access, and lack of safety measures.

Sadly, recent incidents within the UK rail network emphasize the severe safety issues still existing in railway depots. Train driver found dead after being stuck between two trains at Tyseley maintenance facility in Birmingham, West Midlands, on December 14, 2019. This fatal occurrence was caused by key safety shortcomings, according to the RAIB (RAIB, 2020). The research concluded that West Midlands Trains, the depot operator, failed to assess the threats its employees faced and failed to promote safe working practices. This incident emphasizes the need to improve rail depot safety (BBC, 2020). An man was killed when a train operator hemmed him between two trains. The probe found that the 34-year railway veteran failed to utilize one of the depot's safe walking pathways, and the other operator did not warn before running the train because "local instructions did not mandate this." The person may have misjudged the danger or been sluggish. The safety of staff crossing in the stabling depot is one of the main welfare concerns for railway depots. Metro Rail Transit (MRT) and Light Rail Transit (LRT) have always been improving on their staff safety measures on the other hand. For these reasons, this research was initiated: Improved Personnel Safety - Motion Sensor Indicator in dangerous areas of railway stabling depots. This can avoid incidents and provide employees, tourists, and investors a safe environment. In addition, creating awareness and knowledge of the workers and tourists improves security and welfare.

1.1 Literature Review

Railway Depot Safety: A Critical Overview

Railway depots play a very important role in storing, maintaining, and managing trains. However, these facilities often house hazardous zones that pose significant risks to personnel. Injuries or fatalities from railway depot accidents can be extreme, and safety is therefore an important issue. Existing safety technologies and their limitations:

Traditional measures for the prevention of accidents in railway depots include manual monitoring, warning signs, and physical barriers. These have been used for decades. However, these methods cannot efficiently reduce the risks in modern railway depots' dynamic and complex environment (Ahammed et al., 2023).

Manual monitoring is by nature limited because of the constant movement of trains, heavy machinery, and intricate electrical systems. Human error, distractions, and the inability to monitor every area comprehensively may compromise safety (Rail Safety and Standards Board, 2017).

While warning signs are informative, they do not alert personnel in time to dangers nor deter unauthorized access to dangerous zones. Being static signs, they cannot change with dynamic conditions or give immediate feedback necessary to avoid accidents (Li et al., 2022).

Motion Sensor Technology

The solution to the security issues of railway depots lies in motion sensor technology which can detect movement in danger-prone areas in real time for proactive safety measures against potential threats other than the conventional method of which is often deemed lacking (Li & Liu, 2021).

The motion sensors excel in real-time detection of unauthorized or unanticipated movements, triggering warnings for staff and so preventing possible mishaps (Zhu et al., 2020). This characteristic is crucial in dynamic depot situations, since hazards might arise rapidly.

Unlike manual monitoring, prone to human error and tiredness, motion sensors maintain continuous observation of hazardous places, thus ensuring consistent safety in complex and dynamic environments for continued monitoring (Khan et al., 2019). This provides constant awareness that significantly lowers the chance of neglected dangers.

Motion sensors may automatically react to activation alerts by shutting down equipment or alerting security personnel as a safety precaution (Ahammed et al., 2023). Automation provides instant defense, with all possible threats being neutralized with little reaction time.

Types of Motion Sensors and Their Applications

The available motion sensors vary in different benefits and usage in railway depots (Li & Liu, 2021). Selection is done based on the monitored region's needs and qualities.

PIR sensors detect object-generated infrared radiation, making them ideal for tracking human movement (Khan et al., 2019). They can identify illegal people in limited areas because of their thermal signal sensitivity.

Ultrasonic sensors measure the return time of a sound wave after hitting an object. This makes them motion and proximity sensors (Zhu et al., 2020). Ultrasonic sensors may issue warnings when persons or goods approach dangerous equipment or tracking zones.

Microwave sensors detect movement of the object by detecting reflected radio waves. It is excellent for wide ranges and specific materials to detect the movement (Ahammed et al., 2023). Microwave sensors can detect movement in a rail car or be used to monitor large depot sites.

Motion Sensor Technology for Railway Depot: Significance of Research and Development

To maximize potential and handle new railway depot safety issues, motion sensor technology research and development must continue (Khan et al., 2019). Continuous efforts in various crucial areas are included.

Improve sensor location and configuration: Strategically locating motion sensors to maximize the coverage of hazardous zones and avoid false alerts, which may interrupt operations and destroy system trust. This would consider sensor range and sensitivity, depot design, and usual patterns of people and equipment movement (Li & Liu, 2021).

Sensor integration with the safety systems: motion sensors, CCTV cameras, alarm, and access control systems allow combining a complete and effective structure of safety (Zhu et al., 2020). It also covers all aspects and allows for coordinated actions and responses to threats.

Effectiveness of motion sensor applications To enhance safety, the motion sensor needs to be evaluated and its effects taken into account (Ahammed et al., 2023). This involves quantifying false alarms and response effectiveness compared to event volume.

Motion sensor technology significantly provides an opportunity to elevate safety in railway depots. Real-time detection of the presence of individuals, continuous monitoring, and provision of automated responses can help better mitigate risks and prevent accidents against the dynamic environment of any depot. Further research and developments of motion sensor applications would be needed in the railway to ensure the safety and wellness of personnel in these critical transportation hubs.

1.2 Objective of the Study

This study aims to enhance the safety of personnel working in railway depots, particularly in hazardous areas such as maintenance sheds or siding roads. The specific objectives of the study are to:

1. Design the enhance personnel safety: motion sensor indicator in railway stabling depot hazardous zone with the following features:
    1.1. A motion sensor system designed to detect individuals who cross designated outdoor areas near rail tracks. This system should be highly sensitive and capable of accurately identifying human presence to prevent false alarms and ensure that only relevant movements trigger a response.
    1.2. The siren alarm and LED indicator system activate immediately when the motion sensor detects someone crossing the monitored area. This alarm notifies the train operator and other relevant personnel of the potential danger, while LED provides a visual cue for the train operator. It will automatically turn off after the time given to the program.
    1.3. Push button designed to manually operate the Siren alarm and LED indicator system.
    1.4. Camera Surveillance to ensure the Train Driver's Vision over Stabling Area blind spots during track test and entry.
    1.5. Wireless Monitor to Train Driver's Vision in Driver's Cab
2. Fabricate the prototype using the available material in the Philippines Market that would be identical to our design and desired features
3. Test and improve the prototype in terms of using motion sensor sensivity and durability, audio alarm device, and range detection
4. Evaluate the prototype's performance using the Technological University of the Philippines (TUP) standard evaluation instrument.
    4.1. Testing of the prototype aims to validate our study before development starts, identify problems early on, and make necessary amendments.

2. Research Methods

The methodology includes the project's design, development, operation, and testing procedures, and an evaluation system will be provided to assess its effectiveness and usability.

Project Design

The motion sensor indicator is designed to offer a local safety solution for hazardous zones of railway depots. The system has a built-in Passive Infrared motion sensor to detect movement, incorporates a siren alarm, and comprises a Light Emitting Diode indicator for visual and aural warnings. The alarm system also includes a push-button for manual activation of an alarm, a Closed-Circuit Television camera for surveillance monitoring, and a wireless monitor for enhanced visibility. This motion sensor indicator is powered using a solar panel to have continuous runs and less dependency on an extra power source.

Isometric View and Block Diagram

Figure 1 is an Isometric view of the Motion Sensor Indicator Assembled from various components, including the solar panel, siren alarm, LED indicator, PIR motion sensor, signage, push button, and base plate.

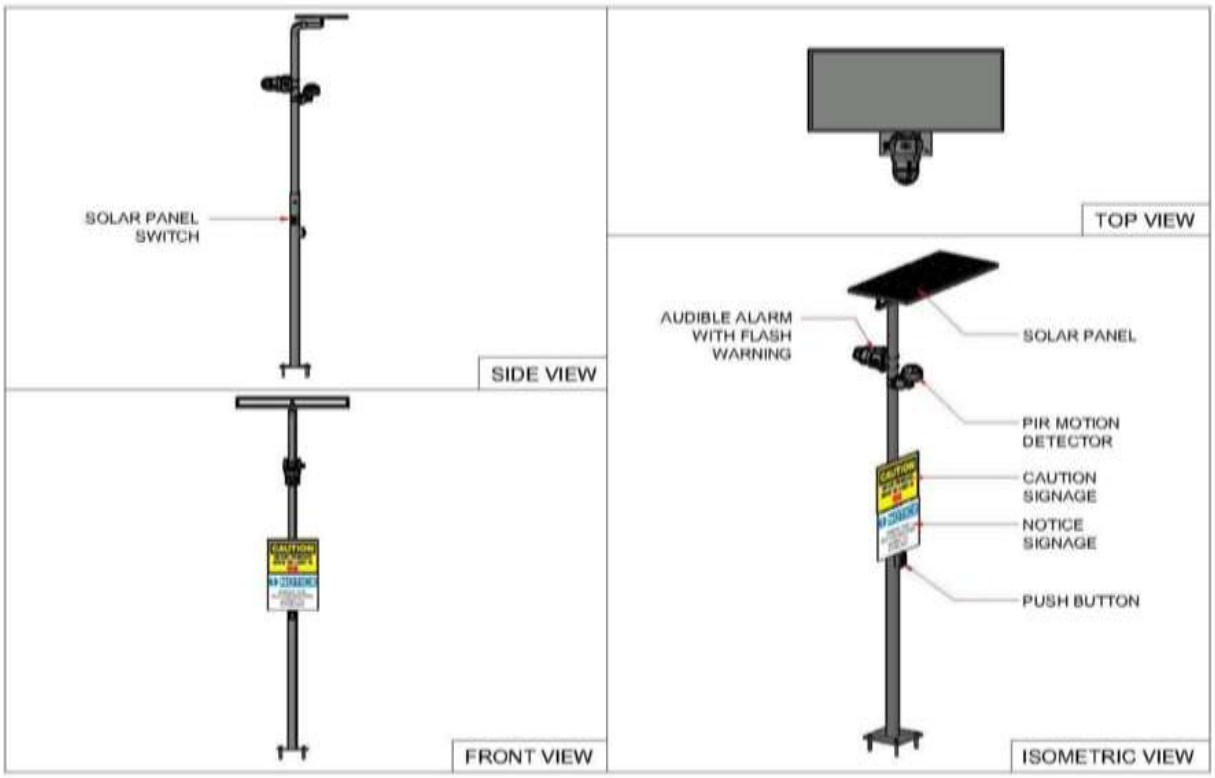

Fig. 1 Isometric View of Enhanced Personnel Safety

Figure 2, the system block diagram, shows the interconnection between the solar panel, inverter, electrical control, PIR motion sensor, warning system, and output components (audible alarm and red light).

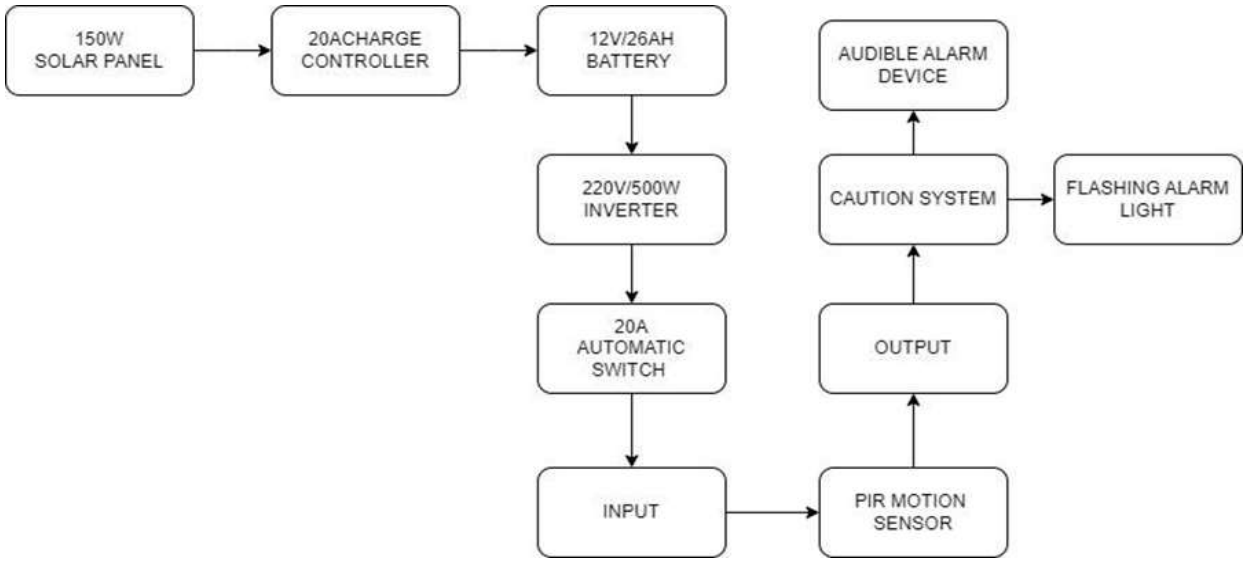

Fig. 2 System's Block Diagram

Project Development

The development of the motion sensor indicator comprises the following major sections:

1. Pole and Frame Section: This section constitutes the indicator's basic structure, comprising a customized round base and a retractable pole.
2. Sensor and Notification Section: This section contains the PIR motion sensor, CCTV camera, red light signal, audible alarm, and wireless monitor.
3. Solar Power Source: This involves the solar panel, charge controller, battery case, and solar inverter.

Fabrication Procedure

It involves constructing the prototype, which is assembled from the various components according to the design specifications, and the operation and testing procedure for the prototype.

1. Operation Procedure: The prototype is powered on by ensuring that the battery case and solar cart are in working condition. The position of the sensor is checked to ensure that it can detect personnel movement in the designated area. Testing Procedure: The researchers conducted a series of tests to evaluate the prototype's performance:
2. Sensor Accuracy Test: This test establishes the functionality of the PIR motion sensor by establishing its detection range and response time at various distances.
3. Luminosity Test: This test measures the luminosity of the red-light signal at various distances to ensure it's visible to personnel.
4. Audibility Test: This test shall check the audibility at different distances so that this alarm can easily alert personnel.
5. Caution Signage Visibility Test: This test measures the visibility of the signage due to caution at different distances so that personnel can understand this signage even in the night darkness.
6. Battery Capacity Test: This test evaluates the battery's capacity to ensure it can be powered by the solar panel and maintain operation for the required duration.
7. Push Button Functionality Test: This test verifies the functionality of the push button in manually activating the alarm and LED indicator.

Evaluation Procedure

The evaluation procedure assesses the improved personnel safety measures using the Technological University of the Philippines' standard evaluation instrument. The evaluation is made through a survey with 30 respondents, including railway students and professionals. A Likert Scale is utilized in the survey to measure various aspects of the prototype's performance, such as functionality, aesthetics, workability, durability, economy, and safety.

3. Results and Discussion

The developed motion sensor indication was tested by the railway students and the experts of the industry. The test was done by the Likert scale, considering major aspects such as usefulness, attractiveness, operability, durability, cost-effectiveness, and safety. Satisfactory responses were shown at higher levels, as the prototype got appreciation in all the categories considered.

Positive evaluation results imply that the motion sensor indication successfully diminishes safety issues in dangerous areas of railway depots. Satisfaction of the respondents with the prototype's utility, aesthetic appeal, operability, durability, cost-effectiveness, and safety implies that it has the potential to be a major upgrade to railway depot safety infrastructure.

Results from the present study are in agreement with other contemporary literature on the potential of motion sensor technology to enhance safety in different industrial environments. There have been several studies that have demonstrated the feasibility of motion sensors in real-time detection, monitoring, and responding to potential threats automatically. This present study extends previous ones by showing the effective use of a localized solar-powered motion sensor indication developed specifically for hazardous areas in railway storage locations.

Effective construction, combined with favorable assessment, of the motion sensor indication, is very crucial towards the safety of the railway depot. The prototype to offer real-time alert notice to workers in potentially risky areas may minimize accidents owing to enhanced workplace safety. Besides, the solar powered architecture will boost the systems practicality and thus adaptability of different kinds of railway depot environment.

4. Conclusions

The research objective for the development of a solar-powered motion sensor indication of localized hazardous zones of the railway depot was reached: a prototype was developed that tested effectively the real-time detection of human movement and triggered audiovisual alarms to improve safety. Successive positive evaluation results, achieved from railway professionals as well as students, validated this system's potential toward reduced risks and prevention in cases of accidents in the environments of railway depots. This research is very relevant to the railway industry because it addresses a critical need for improving measures of safety in railway depots. The motion sensor indicator provides a localized and sustainable safety solution that could reduce accidents and enhance the general working environment for railway personnel. Therefore, the results of the study have wider implications for further research into railway depot safety. Some possible further investigations may be as follows:

1. Optimization of sensor configuration and location in various hazardous zones.
2. Incorporation of supplementary safety features such as automated shutdown mechanisms for machinery.
3. Analysis of the impact of the motion sensor indicator on accident rates over an extended period.
4. Extension of the system to other railway depot environments and operational scenarios.

Limitations of the Research

The limitations of the research are:

1. The prototype was tested in a controlled environment, and its performance in the real world may differ.
2. The study was based on a particular type of motion sensor, and other sensor technologies can be considered.
3. The sample size for the evaluation survey was small, and a large-scale study may yield more robust results.

Recommendations for Implementation

Based on the research findings, the following recommendations are made:

1. Hazardous zones need the motion sensor indicator to increase safety measures in railway depots.
2. The effectiveness of the system is best maintained if its regular maintenance and testing occur.
3. Training courses for railway workers need information on how the system functions and is safe.
4. Future research and development should focus on optimizing the system's functionality and adaptability to many different railway depot environments.

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