IoT Design for a Train Platform Barrier Safety System

Jan Edgar E. Tupas

School of Information Technology, Mapúa University, jeetupas@mymail.mapua.edu.ph

Miguel T. Soniel

School of Information Technology, Mapúa University, mtsoniel@mymail.mapua.edu.ph

Ervin C. Tejada

School of Information Technology, Mapúa University, ectejada@mymail.mapua.edu.ph

Christian Henry Miguel E. Caruz

School of Information Technology, Mapúa University, chmecaruz@mymail.mapua.edu.ph

Railway systems, which carry millions of passengers every day, are essential to urban transportation. However, maintaining passenger safety on train platforms is still a major challenge, especially in Metro Manila, where incidents like dragging and pinning doors have been common. In order to reduce these risks and improve passenger safety, this study proposes an IoT-based design for a train platform barrier safety system. The system employs IoT-controlled alert systems and platform barriers to automate safety procedures, identify possible safety violations, and mitigate risks on train platforms. The system can effectively prevent passengers from falling onto railway tracks and provide timely alerts to ensure passenger awareness and safety by utilizing ultrasonic sensors, microcontrollers, motor drivers, and buzzers. Ultrasonic sensors are used to detect an arriving train, using the distance of the train as the parameter for initiating the operation of the platform barriers. Ultrasonic sensors are further used to detect passengers that are within or surpass the yellow cautionary markers, using the distance of the waiting passenger as the parameter for initiating the alert system. A prototype and simulation were used to assess the viability of the design, demonstrating how IoT technology can be used to enhance platform safety protocols.

CCS CONCEPTS • Computer systems organization~Embedded and cyber-physical systems~Embedded systems • Computer systems organization~Embedded and cyber-physical systems~Sensor networks

Additional Keywords and Phrases: Railway safety, Train platform risk mitigation, Platform barrier system, IoT-controlled alert system, urban rail transit safety

1 INTRODUCTION

1.1 Background of the Study

Railway systems serve a pivotal role as a transformation mode for numerous individuals in the Philippines. The total ridership in public railway lines in Metro Manila was approximately 103.79 million in 2021 [4]. It is vital to ensure the safety of passengers and reduce the risks of accidents, especially on train platforms. Incidents such as door pinning, dragging, and suicide attempts were most common in the Light-Rail Transit from 2004 to 2014 [10]. The absence of safety barriers on train platforms in Metro Manila poses a significant risk to the safety of passengers. Visual cues, including yellow lines and personnel presence, such as security guards, are the current safety measures implemented, as shown in Figure 1, which are insufficient to prevent accidents. Safety barriers, such as platform screen doors, restrict access to the railway track, which reduces incidents of passengers falling on the track [1]. Platform screen doors remain closed when no train is at the station and only open when passengers board or alight from a stopped train at the station, preventing passengers from falling from the railway tracks. Thus, the study addresses a concern about the infrastructure of urban transportation, which aims to improve the safety of passengers and minimize the occurrence of accidents on train platforms. The study tackles the need for enhanced safety protocols in Metro Manila train platforms through an IoT-based solution for train platform safety by implementing platform barriers and alarms through Internet of Things (IoT) technology. This allows for the automation of safety barrier operations and the implementation of sensors that automatically detect and mitigate potential safety breaches in train platforms.

Figure 1: Platform and Railway Track of LRT-1 Doroteo Jose Station

1.2 Objectives of the Study

The lack of barriers in train platforms in Metro Manila limits the guarantee of safety for passengers waiting on the platform. The current implemented safety precautions are limited to visual markers and limited personnel on guard. To address the mentioned problem, the study aims to develop a design for a train platform barrier safety system. The system leverages IoT to automate the process of opening and closing the barriers by detecting the presence of a train arriving at the station using sensors. Additionally, the system will also detect and alert passengers who surpass the waiting markers on the platform to increase safety precautions for passengers on the train platform. The design can be used further to develop a complete train platform safety system for passengers.

1.3 Scope and Relevance

To address the existing gaps in the safety measures currently implemented in Metro Manila train platforms, the proposed system aims to provide a solution applicable to various rail systems in urban settings where the absence of protective barriers on train platforms poses risks to passengers. The study focuses on the development of an IoT-based design for an automatic barrier safety system for train platforms in Metro Manila. The detection and alert of passengers within or surpassing the yellow markers, which pose safety risks, is incorporated in the design. The relevance of the study lies in its potential to significantly improve passenger safety by reducing the risks of accidents of passengers falling on railway tracks while automating the process of ensuring passenger safety. The barrier design is limited to relying on the detection of the train for the automatic opening and closing of the barriers. The study does not tackle the issue of synchronizing the barriers with the train doors. Additionally, the design developed in the study assumes a controlled environment where delays in the opening and closing of the train doors are not considered. This can be tackled in future studies.

2 REVIEW OF RELATED LITERATURE

2.1 Train Platform-related Accidents in Metro Manila

Railways systems are a standard mode of transportation in Metro Manila. The railway sector encompasses the Light Rail Transit (LRT) system, the Manila Metro Rail Transit (MRT) system, and the Philippine National Railways (PNR) system. In 2021, approximately 44.35 million, 11.85 million, 44.01 million, and 3.58 million entries were recorded for LRT1, LRT2, MRT3, and PNR, respectively, showing the significance of public rail systems to commuters [4]. Safety risks are associated with railways despite the implemented safety measures, resulting in accidents that harm the welfare of commuters. In the study of Montano [10], door pinning, dragging, and suicide attempts were the most common safety incidents recorded in LRT1 and LRT2 from 2004 to 2014. The author stated that the LRT system does not guarantee safety among its passengers. LRT1 and LRT2 safety incidents recorded from 2004 to 2014 are shown in Figure 2.

LRT Lines	Incident	Type	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
LRT Line 1	Train Collision	Cases	-	-	-	-	-	-	1	1	-	-	-	2
LRT Line 1	Suicide Intent	Cases	1	4	1	1		1	-	1	2	2	1	14
LRT Line 1	Dragging	Injuries	1	-	-	1	2	2	-	-	1	1	-	8
LRT Line 1	Door Pinning	Injuries	18	23	36	19	29	21	24	39	25	9	15	258
LRT Line 2	Door Pinning	Injuries	-	-	-	49	66	95	40	25	21	7	18	321
		Total	20	27	37	70	97	119	65	66	49	19	34	603

Figure 2: Occurrences of Safety Incidents in LRT1 and LRT2 Stations from 2004 to 2014 from Montano [10]

In the LRT, MRT, and PNR train platforms, there are currently no protective barriers on the edge of the platforms that block access to the railway tracks. The safety measures implemented to ensure the safety of commuters from falling on the tracks are limited to visual markers and personnel or authorities on guard. Thus, multiple instances of commuters falling on the tracks have occurred in the past, leading to severe injuries or death. Table 1 shows instances of train platform-related accidents in Metro Manila in recent years.

Table 1: Instances of Train Platform-related Safety Incidents in Metro Manila

Ref	Year	Railway System	Incident
[5]	2024	LRT-1	17-year old college student suffered injuries after falling from the platform.
[6]	2022	LRT-1	31-year old man lost his right food and was left in critical condition after jumping on the tracks.
[7]	2023	MRT-3	74-year old woman jumped onto the tracks resulting in her death.
[8]	2017	MRT-3	24-year old woman lost her right arm after falling onto the tracks.
[12]	2022	MRT-3	Operations were halted after a male passenger jumped onto the tracks.
[9]	2020	LRT-1	32-year old female sustained head lacerations and bruises from falling on the train tracks.
[13]	2022	LRT-1	31-year old man was run over on the tracks resulting in the detachment of his right foot.

2.2 Impact of Platform Barriers to Passenger Safety

Platform screen doors are a precautionary safety measure that acts as a barrier between people waiting on a train platform and the railway track. It can prevent people from accidentally falling on the track or delay people deliberately attempting to jump on the track. In the study of Cao and Li, the authors determined the correlation between platform screen doors and incidents of passengers falling on the track [1]. The authors noted that accidental falling on the track, careless falling on the track, and being pushed off the platform can be effectively restricted by platform screen doors. Based on the statistical analysis conducted, the authors concluded that incidents of passengers falling on the track when there are no screen doors is higher by 64%, signifying that screen doors can reduce the incidents of passengers falling on the track. In the study of Xing et al., the authors assessed the effects of platform screen doors in reducing incidents of suicides in train platforms [11]. Based on the results, the authors stated that suicide incidents decreased by 90.9% after installing the screen doors. The authors noted that screen doors block access to the track area. This proves that physical barriers can serve as an effective strategy for minimizing the occurrences of suicide incidents on train platforms.

2.3 IoT-based Safety Systems in Railways

Studies leverage IoT technology to improve safety in railways and allow for the automation of safety systems. To address the risks of passengers falling on the rails due to the killer gap, Gilbert et al. proposed a design for a mechanical gap filler to bridge the gap between the train and the platform [2]. Upon the arrival of the train, ultrasonic sensors send a signal to the Arduino, which then operates on the motor to allow the grill to come out. This ensures that passengers boarding and alighting the train do not fall into the killer gap, Meanwhile, in the study of Sahana et al., the authors proposed a railway platform safety system using IoT to address the risks of passengers falling into the railway tracks when boarding or alighting the train by implementing gates [3]. IR sensors are placed at the beginning and end of the station platform and are operated by counter variables. When the first IR sensor detects the arriving train, a signal is sent to the controller, which then signals the motor to rotate, opening the platform gates and allowing passengers to board and alight the train once it has stopped. When the train leaves the station, it is detected by the second IR sensor, which sends a signal to the controller. The motor is signaled to rotate effectively, closing the gates. The authors conclude that the IoT design makes rail transit safer since the platform gates prevent people from falling into the tracks, reducing platform accidents to a large extent. The studies demonstrate the capacity of IoT-based designs for improving the safety of passengers in train platforms.

3 METHODOLOGY

The study proposed an IoT-based design for a safety system in a train platform to automatically operate platform barriers to prevent passengers from falling on railway tracks. The design further incorporates an alert system for detecting and notifying passengers by surpassing the yellow markers on the platform, ensuring that they position themselves at a safer distance. Due to constraints, a prototype and simulation of the design were created and implemented to determine the feasibility of the proposed design. The circuit design was created and simulated using the web application Tinkercad.

3.1 Platform Barrier Safety and Alert System Processes

An overview of the platform barrier system process is shown in Figure 3. Initially, the platform barriers were closed, restricting access to the tracks of the empty station. The operation of the system begins with the approach of the train to the station. An ultrasonic distance sensor is positioned at the entrance of the station to detect the presence of the approaching train. When detected, the sensor computes its distance. A constant threshold distance value is set, which signifies the arrival of the train. The train is near the station if the distance is less than or equal to the threshold distance. Through observation on the LRT and MRT platforms, the length of time between the approach of the train into the station and its complete stop was measured, and an approximate 18-second interval was determined. With this, an 18-second delay is added to account for the time the approaching train takes to stop inside the station entirely. Once the interval elapses, the microcontroller sends a signal to rotate the motor in the direction that opens the barrier. This allows the passengers to alight or board the train. The researchers further observed the LRT and MRT platforms and recorded the time elapsed between the opening of the train doors, followed by the boarding and alighting of passengers, and the closing of the train doors. It was determined through the observation that the entire process took approximately 20 seconds to complete. Given this, a 22-second delay is set before the platform barriers are closed, providing an additional 2-second interval to ensure that the train doors close first. This allows for a short delay between closing the train doors and the barriers. Once the 22-second interval has elapsed after the opening of the barriers, a signal is sent by the sensor to the controller, which signals the motor to rotate in the direction that closes the barrier. In this way, passengers are prevented from walking too close or falling on the railway tracks since access to the area is restricted.

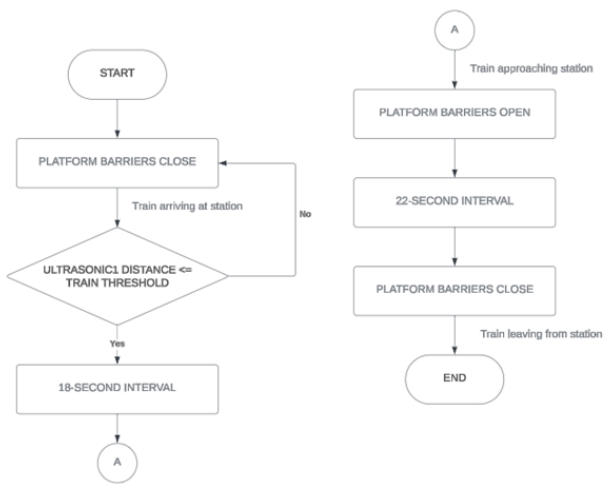


Figure 3: Overview of the Platform Barrier Safety System Process

Figure 4 shows the process for the alert system that detects passengers stepping on or surpassing the yellow markers on the train platform. The alarm will only activate when the barriers are closed, as open barriers signify those passengers are alighting or boarding the train. An ultrasonic sensor is located ahead of the yellow marker. The sensor detects a person who steps on or surpasses the yellow marker by computing its distance. If its distance is less than the threshold, it sends a signal to the controller. Upon reception, the controller signals the alarm system to activate a buzzer and red LED to simulate the process of alerting the person at risk and personnel. This method prevents passengers from being too close to the platform barriers as being too close still manifests risks of falling on the railway tracks.

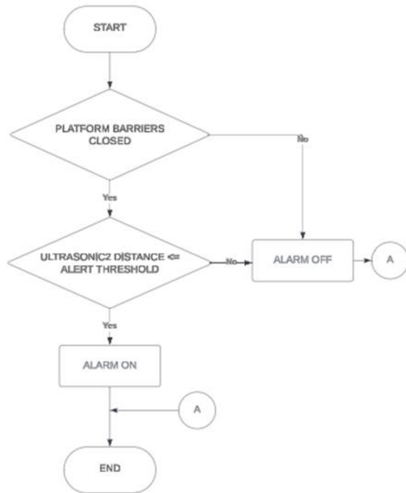
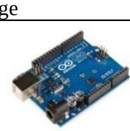


Figure 4: Overview of the Alert System Process

3.2 Design Components of the Platform Barrier Safety System

Table 2 shows and defines the components used for circuit development of the platform barrier safety system. The circuit encompasses an Arduino Uno R3, HC-SR04 Ultrasonic Distance Sensor, DC Motor, H-Bridge Motor Driver L293D, Breadboard, Red LED, and Piezo Buzzer.

Table 2: Components of the Design for the Platform Barrier Safety System

Name	Image	Description
Arduino Uno R3		The Arduino Uno R3 is a microcontroller board based on the ATmega328P. It contains digital and analog input/output pins that can be used to connect to various sensors, motors, and other electronic components. The microcontroller controls and coordinates all other components of the design.
HC-SR04 Ultrasonic Distance Sensor		The HC-SR04 Ultrasonic Distance Sensor is an inexpensive ultrasonic sensor module capable of measuring distances between the sensor and an object using ultrasonic waves. Two sensors will be utilized in the design. One is responsible for determining whether a train is within the station or not. Another is responsible for determining of a passenger is within or surpassing the yellow marker on the platform.
DC Motor		The DC motor is an electrical machine that produces rotational motion by converting electrical energy into mechanical energy. It is responsible for opening and closing the platform barriers, granting and restricting access to the railway tracks.

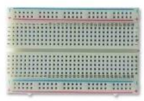
Name	Image	Description
H-Bridge Motor Driver L293D		The H-Bridge Motor Driver L293D is an integrated circuit (IC) used to control the direction and speed of DC motors. It contains two H-bridge circuits, which allow bidirectional control of a motor. It is responsible for directing rotation of the DC motor which dictates the opening and closing of the platform barriers.
Breadboard		The breadboard is a solderless circuit used to create prototypes. It is made up of a grid of holes that is often contained in a rectangular plastic board. Components can be connected and plugged in with ease using the internal connections made in a specific pattern through the holes.
Red LED		The Red LED is a semiconductor device that emits red light when a current passes through it. It can be used as a visual indicator in a circuit.
Piezo Buzzer		The Piezo Buzzer is a tiny electronic sound gadget that emits sound waves in response to an electric signal. It vibrates quickly in response to an electrical signal, producing audible sound waves. It can be used to produce tones, give users audible feedback, or alert users.

Figure 5 shows the circuit setup for the simulation design of the platform barrier safety system. The components of the design include an Arduino Uno R3, two HC-SR04 Ultrasonic Distance Sensors, a DC Motor, a L293D H-Bridge Motor Driver, a Red LED, a Resistor, a Piezo Buzzer, and a Breadboard. The Arduino Uno microcontroller processes all inputs received. Upon running the simulation, Ultrasonic Distance Sensor 1 (US1) emits ultrasonic waves that bounce off an object and return to the sensor, and the duration of the entire process is recorded. This simulates US1, detecting the presence of the train approaching the station. The distance of the train from US1 is calculated by the microcontroller using the recorded duration. The microcontroller evaluates the conditions using the computed distance as input and the distance threshold set to determine when to open the platform barriers. The microcontroller signals the H-Bridge, which determines the direction the DC Motor should rotate, which signifies the opening or closing of the platform barriers. Additionally, Ultrasonic Distance Sensor 2 (US2) acts as the sensor for detecting passengers within or surpassing the platform's yellow markers. If a passenger is detected by US2, the Piezo Buzzer, and Red LED are activated to alarm the passenger and guarding personnel. However, the alarm only activates if the platform barriers are closed. If the platform barriers are open, the alarm is effectively deactivated in all cases since passengers are boarding or alighting the train during this period.

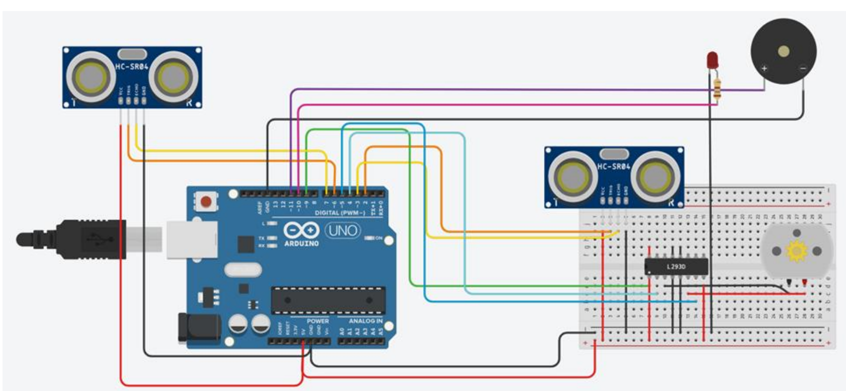


Figure 5: Circuit Diagram

The layout of the proposed platform barrier design is presented in Figure 6. US1 is positioned strategically at the train entrance of the station and faces toward the arriving train to compute the distance of the arriving train. When within the threshold, the operation of the barrier commences. US2 is attached to the platform barrier and faces toward the yellow marker to detect the presence of waiting passengers within the yellow marker. The alarm is initiated when the barriers are closed and passengers are detected within the threshold.

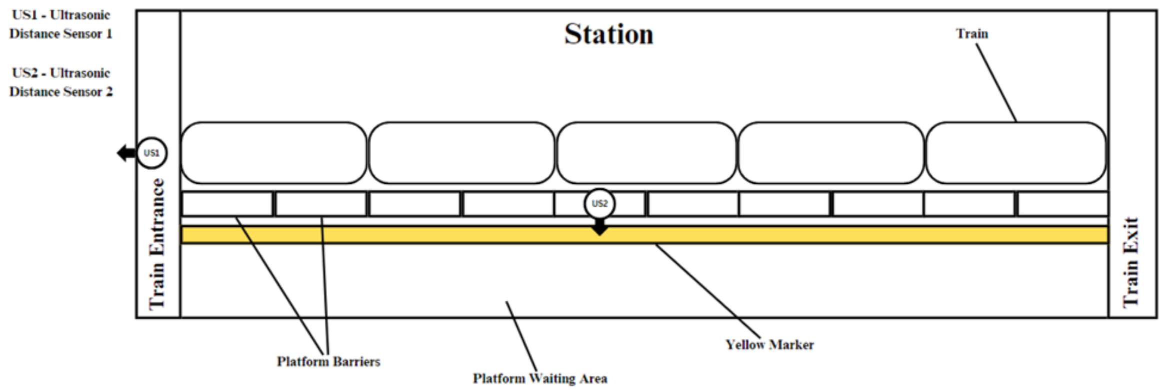


Figure 6: Proposed Platform Barrier Design Layout

Table 3 shows the components and cost of the IoT design used in the study and its description. The total estimated cost of the design is 2186.32 Philippine Peso.

Table 3: Cost Specification

Material	Quantity	Estimated Cost (PHP)
Arduino Uno R3	1	1789.00
Ultrasonic Distance Sensor HC-SR04	2	149.32
DC Motor	1	45.00
H-Bridge Motor Driver L293D	1	45.00
Red LED	1	19.00
Resistor	1	19.00
Piezzo Buzzer	1	65.00
Breadboard	1	55.00
Total		2186.32

3.3 System Pseudocodes

```
const int trainThreshold = 150

  if (distance1 <= trainThreshold && distance1 > 0) {
  deactivateAlarm();
  openBarrier();
}
```

The pseudocode shown above describes the conditions for implementing the operation of opening the platform barriers. The barriers are opened when the distance is less or equal to the specified threshold, which signifies that a train is approaching the station. The alarm system is deactivated, allowing passengers to alight or board the train. For simulation purposes, the threshold is set to 150 cm.

```
void openBarrier() {

  isBarrierOpen = true;
```

```
  delay(18000);
  digitalWrite(motorDirectionPin1, HIGH);
  digitalWrite(motorDirectionPin2, LOW);
  analogWrite(motorEnablePin, 255);
  delay(3000);
  analogWrite(motorEnablePin, 0);
  delay(22000); // Delay before closing barrier
  digitalWrite(motorDirectionPin1, LOW);
  digitalWrite(motorDirectionPin2, HIGH);
  analogWrite(motorEnablePin, 255);
  delay(3000);
  analogWrite(motorEnablePin, 0);
  isBarrierOpen = false; }
```

The pseudocode shown above implements the opening and closing of the platform barrier. As mentioned, an approximated 18-second interval was observed between the arrival of the train at the station and the complete halt of the train. Given this, an 18-second delay is set to take into account the time it takes for the approaching train to come to a full stop within the station. Afterward, the motors are signaled to rotate, opening the barrier. Additionally, an approximate 20-second interval was observed between the opening and closing of the train doors. Thus, a 22-second delay is set, granting an additional 2-second delay to allow the train doors to close first. Once the time elapses, the motors are signaled to rotate, effectively closing the barrier.

```
const int alertThreshold = 100;
 if (distance2 <= alertThreshold) {
  activateAlarm();
 } else {
  deactivateAlarm(); }
```

The pseudocode shown above specifies the conditions for implementing the alarm for passengers within or surpassing the yellow markers on the train platform. When the distance of the detected passengers is less or equal to the threshold, which signifies that a passenger is within or surpassing the yellow markers, and the platform barriers are closed, the alarm is activated. Otherwise, the alarm is not activated. For simulation purposes, the threshold is set to 100 cm.

4 CONCLUSION AND RECOMMENDATIONS

Railway systems are an essential mode of transportation for commuters, especially in Metro Manila. However, train platforms are still dangerous areas as people can easily fall on the railroad tracks and suffer from severe injuries or even death. In the train platforms of Metro Manila railway systems, the implemented safety precautions are visual markers and limited personnel on guard. Due to this, an IoT design for a platform barrier safety system is proposed, which can further strengthen passenger safety. The design encompasses automatic barriers to restrict the access of waiting passengers to the railroad tracks and an alarm system that triggers when waiting passengers are within or surpass the yellow markers on the platform. The design components of the platform barrier safety system use first Arduino Uno R3, which has digital and analog input/output pins to connect sensors, motors, and other electronic components. Second, it uses the HC-SR04 Ultrasonic Distance Sensor that can know the distances between the sensor and the object by using ultrasonic waves. Third, it uses a DC Motor, which creates a rational motion that converts electrical energy into mechanical energy and is responsible for closing and opening the doors. Fourth, it uses the H-Bridge Motor Driver L293D, which controls the opening and closing of the platform barriers. Lastly, the Piezzo Buzzer and the Red LED alarm the passengers and guarding personnel whenever people are beyond the yellow markers on the platform. The design was simulated using the web application Tinkercad. The simulation ran successfully and showed the viability and feasibility of the automated platform barrier and alert system design. However, the design is limited to assuming a controlled environment where the duration for the opening and closing of the train doors are constant and uniform at all times and there is no delay. Future researchers could further improve the system by exploring and utilizing other sensors to detect the automatic closing and opening of the train doors and synchronize the opening and closing of the platform barriers. In this way, delays and time variances are taken into account. Additionally, further testing should be implemented to ensure the reliability and accuracy of the system apart from conducting simulations. Furthermore, by conducting user studies, future researchers can gather feedback from passengers, station staff, and guards to assess the usability and effectiveness of the system when deployed in the actual train station.

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