Automatic Railway Gate System for Commuter Line Train Based on Sensor Accelerometer and Microcontroller

Erna Kusuma Wati[1], Novi Azman[2], Fitria Hidayanti[3], M. Fikri Ananda[4]
[1,3,4]Department of Physical Engineering Program, Universitas Nasional
[2]Department of Electrical Engineering Program, Universitas Nasional
e-mail: ernakusuma.w@gmail.com

Article Info

Article history:

Received 18 No 2021
Revised 27 Jan 2022
Accepted 16 Mar 2022

Keywords:

Automation
Railway Gate
Accelerometer
Commuter line
Microcontroller

ABSTRACT

There have been many designs for the automatic closing gate to reduce the number of accidents at railroad crossings, but no one has tested it directly when the train is passing. This study will design an automatic railroad gate closing system that is tested on crossing KRL commuter trains that can be recommended to PT. Commuter Indonesia to improve safety at railroad crossings. The Accelerometer sensor is system one as a vibration detector of a passing train, and Arduino UNO or system two will give commands or control the train gate to open and close automatically. System testing was carried out on ten commuter trains crossing the Jakarta-Depok route with variations in distance. Variations in time intervals of 200m, 450m, and 650m were carried out to obtain the time difference between the closing of the train gate completely and the time when the train passed at the gate crossing with standard time. The test results at a distance of 200 meters have a time difference of 2.9 seconds with an average value of 10.01 m/s2, at a distance of 450 meters for 14.1 seconds; g 10.01 m/s2, and at a range of 650 meters for 36.7 seconds the value of g is 10.02 m/s2. The results of the study recommend placement with a distance between systems of 650 meters.

Corresponding Author:

Erna Kusuma Wati,
Department of Physical Engineering Program,
Universitas Nasional,
Jl.Sawo Manila, No.61 Pejaten, Ps. Minggu, Jakarta Selatan.
Email: ernakusuma.w@gmail.com

1. INTRODUCTION

Commuter line (KRL) trains are electric rail trains that move using an electrical motor propulsion system which is the transportation of choice that is quite attractive to residents in the city of Jakarta, Indonesia. Besides being cheap, KRL is a transportation that can avoid congestion in the capital city and can carry passengers in bulk. KRL has long operational hours to facilitate commuters in the Greater Jakarta area. This will affect the level of traffic density on the KRL lane, so it is necessary to maintain and improve safety to avoid the risk of accidents with highway users at the railroad crossing. Based on observations made on the Jakarta-Bogor KRL route, there are still some railroad crossings that do not yet have a doorstop gate that works automatically but is operated manually by a guard officer. This makes motorcyclists and cars undisciplined because guard officers sometimes still allow motorists to pass because the KRL is still far away. So, it becomes a matter of habit to pass through the gates of the train, even though it is dangerous to their safety because it can cause accidents. The railroad gates that are operated manually by guard officers also have a high risk for accidents resulting from the carelessness of officers [1] . Therefore, it is necessary to design an automatic system to open and close the train gates, to avoid and reduce the risk of such accidents.

Several researches on the design of automatic railroad crossing gates are using ultrasonic sensors to detect congestion, and the train crosses paths based on reflected waves, so it can sound an alarm, detect light signals, and control the gate [2] . Other research uses infrared sensors to detect the arrival and departure of trains at railroad level intersections and Arduino to control open/close gates [3] . The design of the Automatic Railway Barriers Security System using the Inductive Proximity Sensor based on the Atmega 328 is used to create a railroad crossing gate automatically. By using train imitation as a prototype of a real train, Atmega328 microcontroller, inductive proximity sensor, and DC servo motor [3] The test was repeated ten times. Automatic train bars can detect metal-coated trains, while non-metal-covered trains cannot be detected. The system is capable of displaying train speed measurements by using a Micro Controller, L293D (motor driver), stepper motor, and resistors. IR LED can also create an automatic railroad crossing gate system [4] . This system uses two IR sensors to detect train arrivals and a third IR sensor to detect train departures [5] When the train's arrival is felt, a signal is provided for traffic that shows the train's arrival on the track. When the second sensor detects the train, the signal turns red, and the motor operates to close the gate. The gate remains closed until the train is fully moved away from cross level. When the train's departure is detected by a third sensor, the traffic signal turns green, and the motor operates to open the gate. Other research that designed the automatic system of railroad crossing gates is by analyzing the determination of vibration threshold originating from railroad vibrations when the train passes. The vibration threshold is used for the detection of train arrival processes in a vibration-based hook system [6] [5]. The sensor threshold will be sent to the coordinator as a decision to close the train gate. But the train gate automation system in the research study has only been applied to mini trains or has not been implemented on real trains. This research was conducted based on existing researches on automatic open and close railroad gates system, which creates an automated system for opening and closing railroad gates, that are tested directly on real trains that cross the railroad crossings.

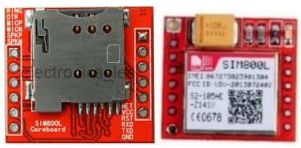
This research will design an automatic system to open and close the railroad crossing gates, which also able to display the vibration data acceleration of a passing train. The results of the design will be applied directly to the commuter line KRL crossing route Jakarta-Depok route. This research requires two systems; the first system is a real vibration detector from KRL using accelerometer sensors [7] and the second system is an automatic crossing gate of the train crossing. KRL vibration measurement was conducted to analyze the determination of the vibration threshold originating from rail vibrations when the train passes [8] The sensor threshold will be used as a set point on the microcontroller to output the servo motor, buzzer, and LED on the second system. so the system can automatically open and close the railroad crossing gates. Communication to give commands between systems one and two is via GSM mode. The results of the design of an automatic railroad crossing system in this research will be recommended to PT. Indonesian commuter as manager of Jabodetabek KRL Commuter Train and its surroundings, to make all railroad crossing gate systems work automatically (no longer manual) and reduce the risk of accidents at crossing railroad crossings.

2. MATERIAL AND METHOD

2.1 Research Materials

Research on the design of commuter line railroad crossings automatically using the accelerometer sensor was carried out at the KRL railroad crossing at Pondok Cina station, Depok, West Java, Indonesia. The hardware that will be used in this study are; Arduino Uno R3, Accelerometer ADXL345 [9] USB Port Cable, notebook, LED, Buzzer, Stepper Motor, and GSM Module while the software uses Arduino IDE and Fritzing.

ADXL345 Accelerometer



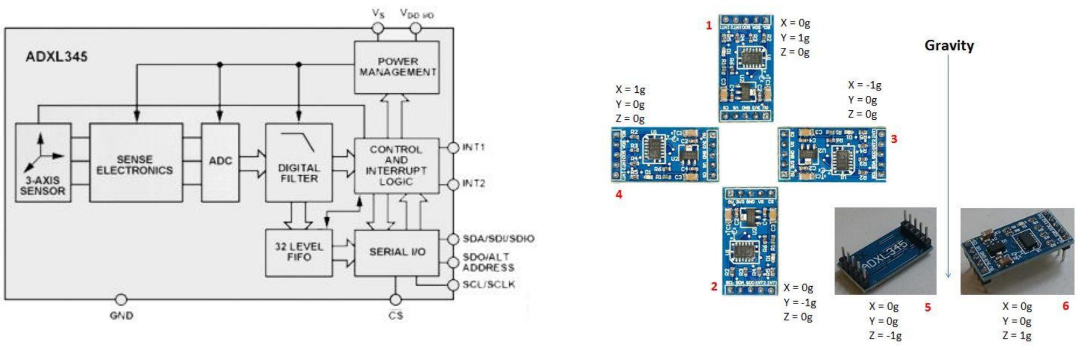
SIM800L GSM Module

buzzer

Arduino UNO Microcontroller ULN2003 Driver Step Motor 28BYJ-48

Figure 1. Hardware components

The design of the train gate automation system in this research will be applied directly. In real-time, so the initial stage of this research is to measure the vibration value of the KRL that passes by using the Accelerometer ADXL345 [10][11] . The acceleration rate produced by the KRL is the lowest set point as input data in the programming language in the Arduino IDE to output the servo motor, buzzer, and LED**.**



(a) (b)

Figure 2. a) ADXL345 block diagram, b) Gravity orientation and ADXL35 output response

2.2 System design

The initial stages in this research are designing the vibration detection system (system 1) and automatic railroad gate gates (system 2). System 1 uses the accelerometer ADXL345 sensor to detect the vibrations of the passing trains. The Arduino Uno microcontroller processes the signals then give commands to the GSM SIM800L module. The module communicates with the GSM SIM800L module on system 2, then the next data will be processed by Arduino Uno in system 2 to power the servo motor, LED, and buzzer.

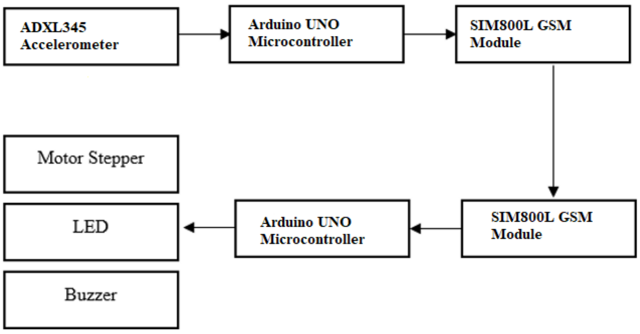


Figure 3. System Diagram Blocks

2.2.1 Designing ADXL345 and SIM800L with Arduino UNO (The vibration detection: system 1)

The design of the ADXL345 with Arduino UNO uses available pins with a 5-volt voltage. This stage begins by connecting the ADXL345 Arduino UNO to the computer using a USB cable. Next is programming the Arduino IDE software utilizing the programming language so that the ADXL345 can read the vibrations of a passing train and SIM800L on system one has to send it to the SIM800L module installed on system 2. If the program is correct then the vibration value will be seen on the serial Arduino IDE monitor in system 1, using a voltage regulator serves to reduce the current that will enter the SIM800L to avoid damage.

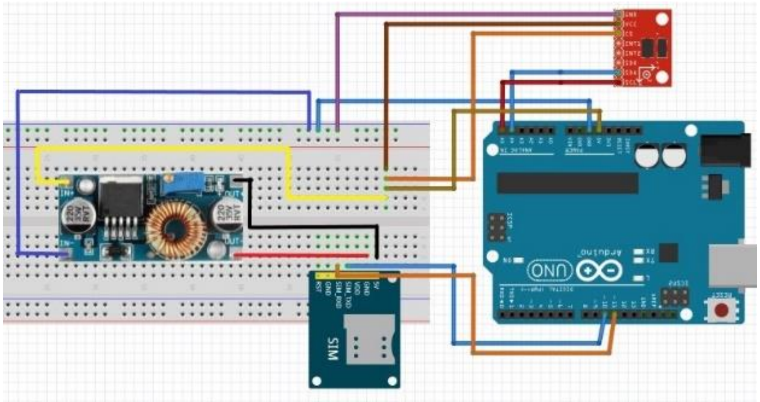


Figure 4. Electronic design on system 1

In the electronic circuit above (Figure 4) the pins that must be connected between ADXL345, SIM800L, and Arduino UNO which will operate are as follows:

- Ground Pins (GND) on ADXL345 and SIM800L are connected to Ground Pins (GND) on Arduino UNO.
- The VCC pin on SIM800L and Chip Select (CS) on ADXL345 is connected to the 5v pin on Arduino UNO, which is used as a power supply for both.
- The pin (SDA) of the ADXL345 is connected to the A4 pin of the Arduino UNO.
- The pin (SCL) on ADXL345 is connected to pin A5 on Arduino UNO.
- The TXD pin on SIM800L is connected to pin ten on Arduino UNO
- The RXD pin on the SIM800L is connected to pin 9 of the Arduino UNO.

The position of the Sensor Accelerometer (system 1) is directly above the commuter line (KRL) railroad bearings like the placement of sensors in another research.

Figure 5. The illustration of the position of the system one

2.2.2 Design of SIM800L and Railroad Bars (automatic railroad gate gates: system 2)

The design of components in system 2 consists of a Stepper Motor, LED, and Buzzer with Arduino UNO using available pins with a voltage of 5 volts. It starts by connecting the Stepper Motor, LED, and Buzzer with Arduino UNO to the computer using a USB cable. The next step is programming the Arduino IDE software utilizing the programming language so that the system can work well. The SIM800L in mode 1 sends an SMS command to close the gate and SIM800L with an Arduino connected to the bar will accept it and move the motor and turn on the LED and buzzer. Figure 7 is a series of electronics for each component in system 2.

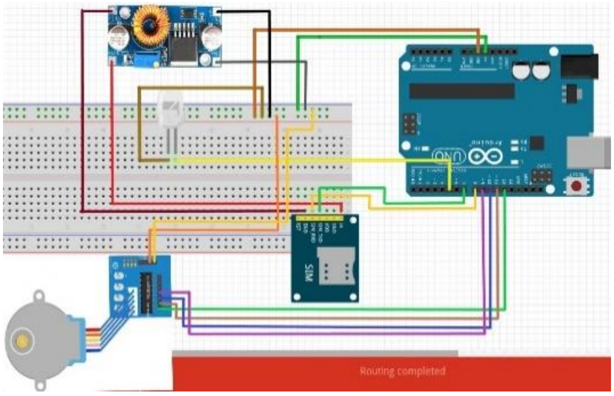


Figure 6. Electronic design on system 2

Here are the pins that must be connected to the electronic circuit in system 2:

- The Ground Pin (GND) on the LED, Buzzer, Stepper motor, and SIM800L are connected to the ground pin (GND) on Arduino UNO.
- The VCC pin on the SIM800L and the VCC pin and the VCC pin on the stepper motor are connected to the 5v pin on Arduino UNO, which is useful as a power supply for both.
- The positive pin on Buzzer is connected to pin four on Arduino.
- A positive pin on the LED is connected to pin five on Arduino.
- The TXD pin on SIM800L is connected to pin seven on Arduino UNO.
- The RXD pin on SIM800L is connected to pin eight on Arduino UNO.
- IN1, IN2, IN3, and IN4 on the stepper motor are connected to pins 9, 10, 11, and 12 on Arduino.

The automatic gate train which is moved by a stepper motor is designed with a height of 25 cm pole, with the length of the crossbar is 30 cm.

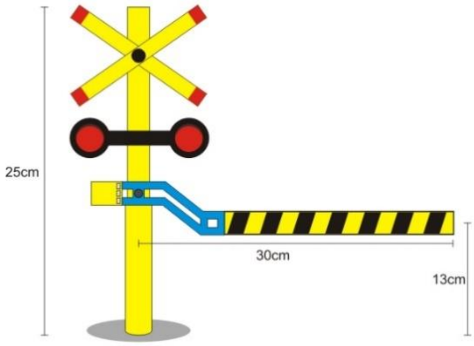


Figure 7. crossing gate design of the train

2.3 System testing in the commuter line railroad crossing

The testing of the railroad crossing gates automatic system taking place at the commuter line KRL railroad crossing line Pondok Cina Station, Depok, West Java. The retrieval of the data testing is by varying the distance between the vibration sensor (system 1) with the automatic railroad gate (system 2). The first test is at a distance of 200meters, the second test at a distance of 450 meters, and the third test at a distance of 650 meters. The parameter or event as an indicator of success in this test is the time in seconds:

(1) the commuter railroad gate will close,
(2) the commuter railroad gate will close correctly,
(3) the commuter line train crosses,
(4) the commuter line train has finished passing, and
(5) the gate of the commuter train cross will open.

In detail, the laying of system one and system two at the location of data collection is shown in figure 2. The variation of the distance of 200m, 450m, and 650m is the distance of system 1 to system 2 [22]. This is done to obtain data variations when testing sensors

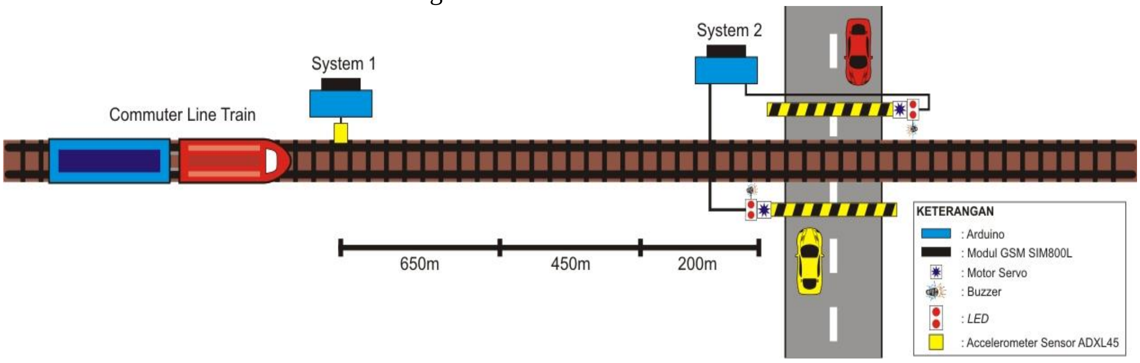


Figure 8. System position one and system two at the test location

For each of these variations, 10 data is collected on ten commuter line trains that pass. Figure 9 is the flowchart of the automatic railroad gate system when the train passes.

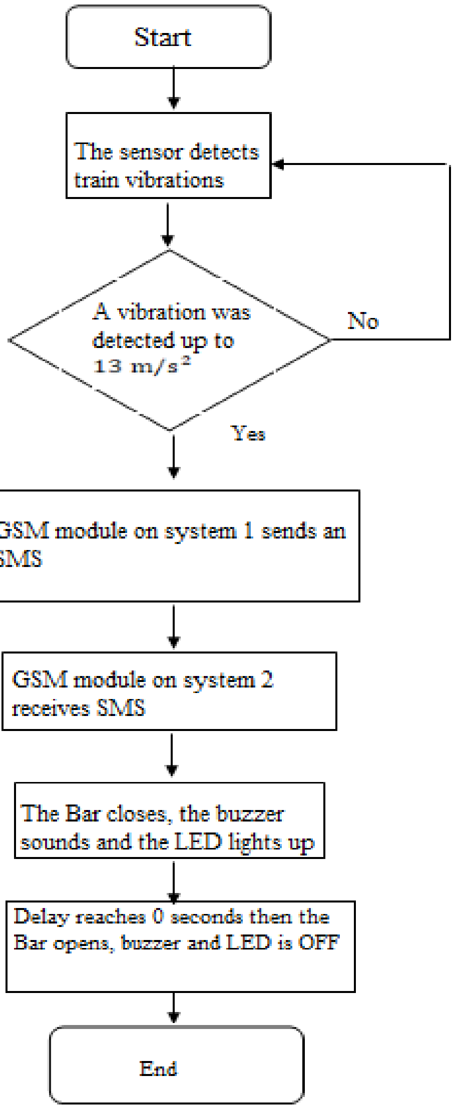
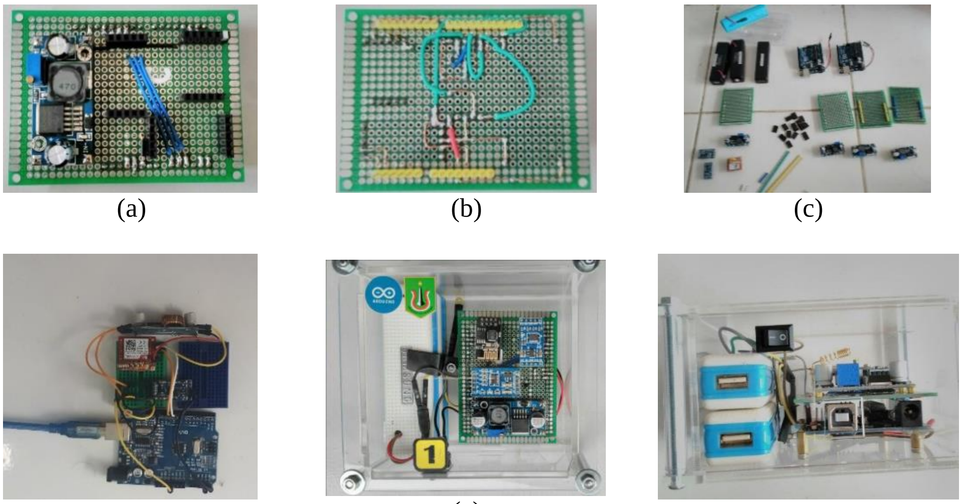


Figure 9. flow chart of the measurement system as the train passes

3. RESULTS AND DISCUSSION

3.1 Vibration detection system

A vibration detection system (system 1) measures the vibrations of a passing train. The components of system 1 are ADXL345 sensor, GSM SIM800L Module, Xl4005 Voltage Regulator, Arduino UNO, power bank, and connected to the laptop.



(a) (b) (c)
(d) (e) (f)

Figure 10. (a) (b) (c) (d) Electronic Component Design and (e) (f) photos of vibration detection devices on system 1

This System 1 can work if the sensor is connected to Arduino UNO and power supply, and will carry out commands according to the instructions that have been made with the Arduino IDE software application.

1. Arduino UNO that has been programmed with Arduino IDE will give an ADXL345 accelerometer to measure vibrations that occur around the railroad tracks when the train passes.
2. ADXL345 accelerometer sensor will take the acceleration data from vibration measurements; the data received is the only acceleration from the z-axis.
3. If the vibration value has reached a certain point (set point), Arduino UNO will give a command to SIM800L that was previously programmed with Arduino IDE to send a message to SIM800L on the system 2.
4. After SIM800L sends the first command message (closes the gate), then the system will delay some time to send the second command message, which is to open the automatic crossbar and turn off the LED and Buzzer.

3.2 The result of the automatic railroad crossing system on system 2

The automatic railroad crossing system (System 2) consists of a Stepper Motor, LED, and Buzzer, with Arduino UNO using available pins with a 5-volt voltage. The Stepper Motor, LED, and Buzzer with Arduino UNO are connected to a computer using a USB cable. System 2 can operate if SIM800L and Stepper Motor have been connected to Arduino UNO and power supply, and then will carry out commands according to the instructions that have been made with the Arduino IDE software application.

1. SIM800L on system two will receive a message from SIM800L (mode 1) and forward it to Arduino UNO.
2. Arduino UNO programmed with the Arduino IDE will give the Stepper Motor, LED, and Buzzer commands to light up, and the bar will automatically close.

3. Then the bar automatically opens if SIM800L has received the second command message from SIM800L (system 1).

Then commands will be created as a commands list that will be uploaded into Arduino UNO. This program will read the acceleration value that occurs on the z-axis that is read on the ADXL345 sensor. After all the commands have been completed, the next step is to connect the Arduino UNO to the laptop using a USB cable. To upload the commands is by clicking the "upload" button on the Arduino IDE application as seen in figure 11.

Figure 11. Tools Arduino IDE

3.3 The Automatic result testing of the gate door of the train at the KRL commuter line crossing

If the design has been successfully made, then the next step is to test the system before use in the field. The test is as follows.

3.3.1 Sensor Testing

The sensor was tested using a sensor program to detect vibrations on the Z-axis produced by the ADXL345 sensor [21-25]. At rest, the sensor should read the vibration acceleration of 1g (9.8 m/s^2). To determine the balance of the sensors, the smartphone application "Precise Level" was used.

Table 1. The test data is vibration acceleration on the Z-axis when the sensor is at rest

Data	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	18	20	21	22	23	24	25
g sensor (m/s^2)	9.7	9.8	9.7	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.7	9.8	9.8	9.8	9.8	9.8	9.7	9.8	9.8	9.8	9.8	9.8	9.8	9.8
g constant (m/s^2)	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8

Table 1 shows the value of g is always constant at 9.8 m/s^2, which is the actual g, while the g sensor is g whose graph is up and down. It can be seen that the sensor used in this study is functioning correctly with an average acceleration of 9,795 m/s^2. from this data, it is known that the sensor works well.

3.3.2 SIM800L testing for communication between sensors

SIM800L is used as communication between sensor components (system 1) with automatic train bar components (mode 2). SIM800L module testing is shown in figure 12. Figure 12 show that when the ADXL345 sensor reading reaches more than 13 m/s^2, SIM800L communicates directly with the automatic bar (system 2) by sending the message "LIHT ON", and then the doorstop will automatically close

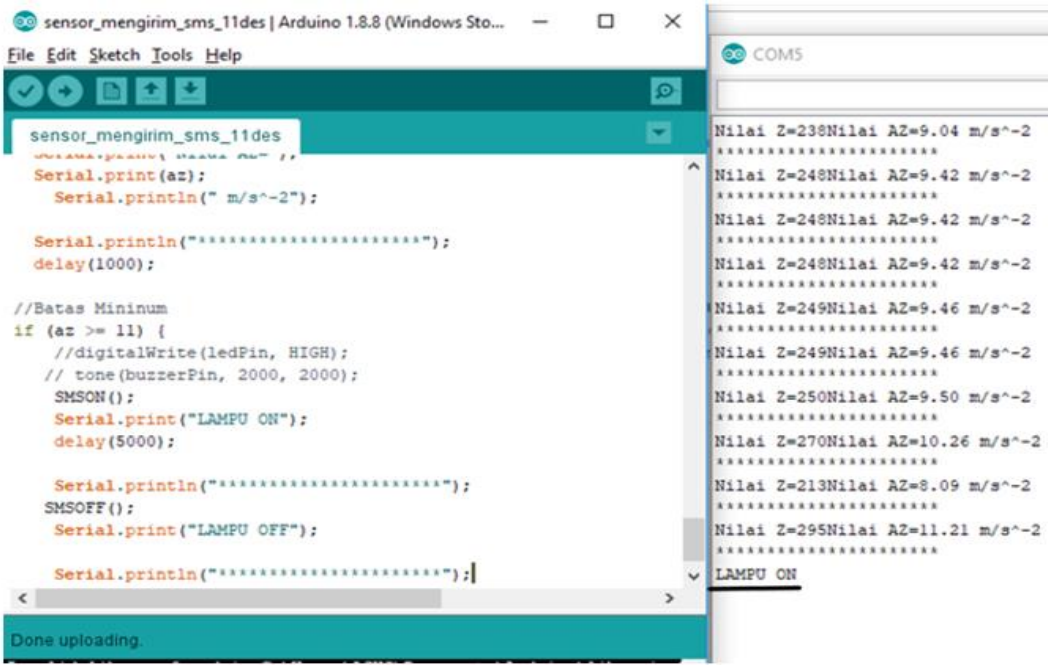


Figure 12. Command Lights On

After the "LIGHT ON" command is sent, Arduino will delay 35 seconds for testing the 200m sensor distance from the automatic bar, 50 seconds delay for testing the sensor distance 450m from the automatic bar, and 70 seconds delay for testing the 650m sensor distance from the automatic bar. After a delay of the specified time the SIM800L will give a message again, but this time to open the automatic bar with the message "LIGHT OFF".

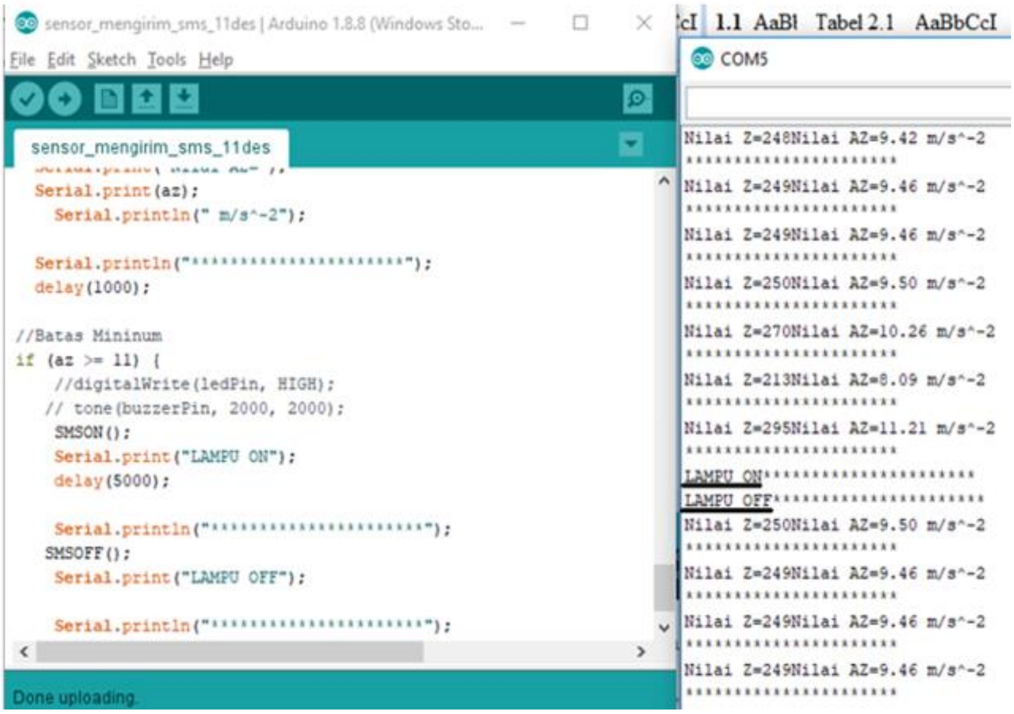


Figure 13. Command Lights Off

Afterward, the next step is testing the SIM800L to receive SMS from the two commands given on the sensor component (system 1). Figure 13 is the result of the test. When the SIM800L mounted on the automatic bar (system 2) receives the message "Light ON", the doorstop will automatically close and the LED and buzzer will light up as a warning that a train will pass

3.3.3 The system test results when the KRL commuter line trains cross

The system that has been successfully designed and tested then can be used to retrieve real data in the field. System testing is done directly when the KRL commuter line train passes (Figure 14).

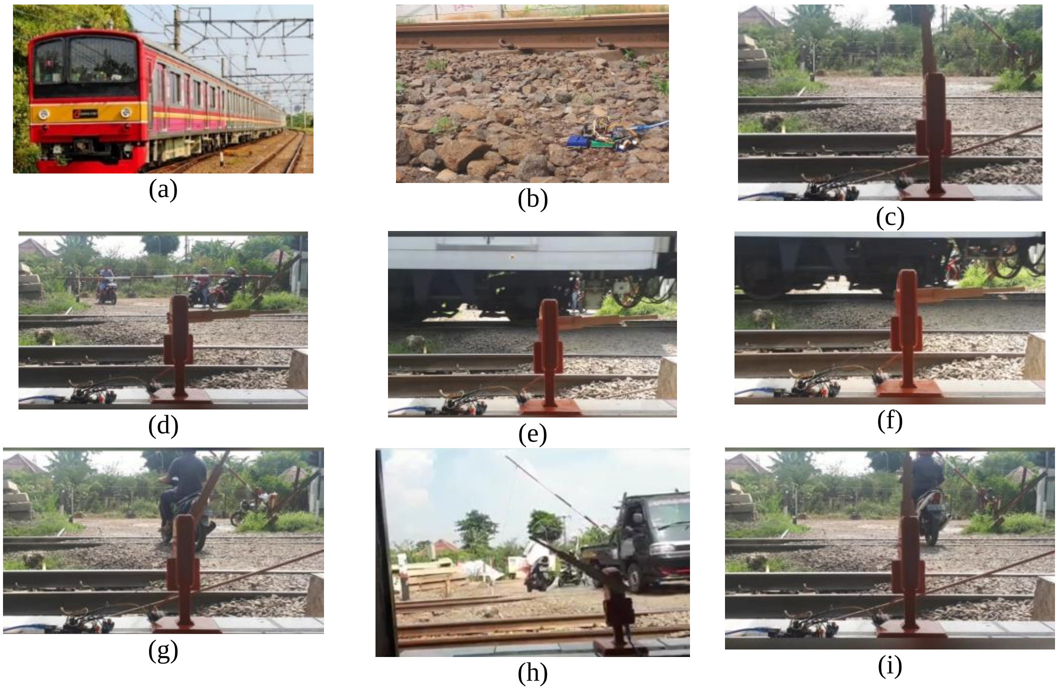


Figure 14. Documentation of the automatic doorstop system field testing at the KRL commuter line crossing a) KRL commuter line, b) position of the Sensor Accelerometer, c) the gate crossbar hasn't closed yet, d) the gate closes, e) and f) The KRL commuter line passes, g) h) and I the gate crossed open.

Data collection was carried out ten times the trains passed on the railroad crossing gate. Table 2 shows the average measurement result of ten trains that passed with the distance variation between systems 1 and 2 is 200m, 450m, and 650m.

Table 2. Average time measurement result data for ten passing trains

No	Events	Testing at a distance (Meters)		
		200	450	650
1	Cross closes on (Seconds to)	20	20	20
2	KRL commuter line Passing (Seconds to)	22.9	34.1	56.7
3	The time lag between the crossbar closes perfectly with the KRL crossing (Seconds)	2.9	14.1	36.7
4	KRL Completed Passing (Seconds to)	32.5	44.7	66.3
5	Opening Bar (Seconds to)	39.8	52.3	72

Table 2 shows the data of the average time measurement result on several events which are when the crossing gate closes when the train crosses and finishes passing, and the crossing gate opens. Variations in the distance are carried out to obtain a time that is appropriate or close to the standard time difference between the crossbar gate closing perfectly and the train that will pass.

Test results on events, the time for the train to pass, and the time to open the railway gate show different results. This is because the number of train cars that pass when doing the test is different. So the parameters to be analyzed are the time difference between the train gate automatically closing perfectly and the passing train. The averages of the three tests are shown in Table 4, which then is compared with the results of the analysis in theory.

The length of each KRL Commuter Line car is 20 meters. The number of KRL cars varies from 8, 10, and 12. The distance between one crossing and the next is less than 800 meters. And the speed of the trains when passing at the crossing is less than 60 km/h. The length of the train's crossbar is about 7-9 meters, with a closing time of 7-13 seconds if the minimum distance between one crossing and the next pass is as far as 800 meters. Then we can make an analogy to obtain the standard closing time of the bar as follows:

$$t = \frac{s}{v} \tag{1}$$

The length of track (s) = 800 m
Velocity (v) = 60 km/h

$t = \frac{s}{v} = \frac{800\ m}{16{,}7\ m/s} = 57.9\ sec$

57.9 seconds is the arrival time of the KRL line commuter train at the crossing gate. Then to calculate the time lag between the gate crossing closed completely with the passing train is as follows:
= 57.9 sec - 13 sec
= 34.9 seconds

Table 3 is the average of the test results at distances of 200m, 450m, and 650m. The difference or time lag between the gate of the crossing closing perfectly with the time the train passes is a concern in this limitation. Based on theories and applicable regulations, the time standard is 34.9 seconds. So of the three tests that have near-perfect results are testing at a distance of 650m with an error of 0,02 %. Thus this automated system can run well and can be given as a recommendation to PT. KAI to improve road safety and safety at the railroad crossings.

Table 3 . Comparison of Average Test Results With Theory

Events	200m	450m	650	Theory
The time lag between the crossbar closes perfectly with the KRL crossing (Seconds)	2.9	14.1	36.7	34.9

Each variation of a distance of 200m, 450m, and 650m is taken on ten trains that cross the line. in addition to measuring the time of some of the events shown in table 2, the results of this study can also display the vibration data of acceleration of commuter line trains in real-time (see table 4)

Table 4. Acceleration of train vibration data on distance testing

No	Acceleration of train vibration data on distance testing			g constants
	200 m	450 m	650 m	
1	10.01 m/s^2	10.01 m/s^2	10.02 m/s^2	9,8 m/s^2

Table 4 is the average data of acceleration vibration recorded from 10 trains that pass at each distance variation. For each crossing train, the acceleration vibration data is taken eight times from when approaching the vibration sensor to moving away from the sensor.

The test results and measurement data in this study indicate that the automatic system of the railroad gate to open and close can work well. ADXL345 vibration sensor on system one can detect train acceleration vibrations accurately and adequately to indicate the threshold of vibration value, which will be used as an Arduino Uno microcontroller command. Communication system 1 with system two that uses GSM SIM800L also works well so that the Arduino UNO microcontroller moves the servo motor, and turns on the LED. The buzzer to close the gate so that the microcontroller, as well as the use of delay time to give commands in opening the railroad gate, can also function well. This can be seen based on the results of the measurement of time on several recorded events (Table 2). An error value of 0.02% in the time lag between the crossbar closing perfectly with the KRL crossing (Table 4) is due to several reasons. First, the time measurement of some events is still done manually using a stopwatch, data recording should be recorded automatically. Then another factor is due to the system is designed to use delay time to give orders between system 1 to system 2. It is necessary to add other sensors such as IR, LDR, or other sensors. In addition, to reduce the error value and make the system work more automatically, it can also be made to anticipate that if there is a commuter line train that stops at a crossing, the gate gates do not open. The system designed in this study does not yet have a data logger, so data retrieval is based on the results of monitoring in real-time through a notebook. Data retrieval in this study is based on monitoring results in real-time through a laptop, so this research must display time data on several events, train acceleration vibration data via LCD which is also based on the Internet of Things (IoT), or has a data logger on the system.

4. CONCLUSION

The test results and measurement data in this study show that the automatic gate system to open and close can work well. The ADXL345 vibration sensor in the network can detect train acceleration vibrations accurately and sufficiently to indicate the threshold value of the wave, which will be used as an Arduino Uno microcontroller command. The communication system 1 with system 2 that uses GSM SIM800L works properly so that Arduino UNO can control and give commands to drive the servo motor, turn on the LED and buzzer so the gate closes the door, and use the delay time to give commands to open the train gate. System testing is carried out directly on the train, varying the distance between system 1 to system 2, namely 200m, 450m, and 650m. At the distance of 650 meters, the resulting time difference between the railroad gates closing perfectly and the train arrival is 36.7 seconds with an error value of 0.02%, compared to the standard time with $g = 10.02\ m/s^2$. Thus the results of research on the design of an automatic system based on the accelerometer and microcontroller railroad gates placed with a distance between the systems as far as 650 meters can be recommended to PT. Commuter Indonesia makes all railroad crossing gate systems work automatically and improves road safety at railroad crossings.

REFERENCES

[1] Al-Zuhairi, M. A. (2013). Automatic Railway Gate and Crossing Control based Sensors & Microcontroller. *International Journal of Computer Trends and Technology (IJCTT)*, *4*(7).

[2] Chellaswamy, C., Srinidhi Srinivasan, and R. R. B. (2014). A humanitarian intelligent level crossing controller utilizing GPS and GSM. *IEEE Global Humanitarian Technology Conference-South Asia Satellite (GHTC-SAS).*

[3] Chetty, Kevin, Qingchao Chen, and K. W. (2016). Train monitoring using GSM-R based passive radar. *IEEE Radar Conference (RadarConf).*

[4] Jiang, Bo, et al. (2014). Railway vibration monitoring system based on ARM and acceleration. *2014 9th IEEE Conference on Industrial Electronics and Applications*.

[5] Krishnamurthi, Karthik, et al. (2015). Sensor based automatic control of railway gates. *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*, *4*(2), 539–543.

[6] Mahmud, Saifuddin, Ishtiaq Reza Emon, and M. M. B. (2015). Automated railway gate controlling system. *International Journal of Computer Trends and Technology (IJCTT)*, *27*(1).

[7] Potdar, Apurva S., et al. (2017). Wireless sensor network for real time monitoring and controlling of railway accidents. *International Conference on Trends in Electronics and Informatics (ICEI).*

[8] Sakthivel, K., and R. S. (2018). Design Of Automatic Railway Gateoperator. *International Journal of Pure and Applied Mathematic*, *119*(112), 5441–5448.

[9] Suharjono, Amin, Eni Dwi Wardihani, and Y. F. K. H. (2017). Analysis of the vibration signal detection for rail train arrival. *IEEE International Conference on Communication, Networks and Satellite (Comnetsat).*

[10] Waghmare, Akash, et al. (2020). Automatic Railway Gate Controlling and Smart System of Railway Gate Crossing using IoT. *Recent Trends in Information Technology and Its Application*, *3*(2).

[11] Yılmazlar, Eray, et al. (2018). *Design Of Stepper Motor Control Interface With Embedded Systems*.