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Designing a Pedestrian Crossing Aid Prototype Based on Arduino Mega

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ABSTRACT

Pedestrian safety at road crossings is a critical global challenge, with the World Health Organization reporting that pedestrians account for 23% of all road traffic deaths worldwide. In rapidly urbanizing areas like Cibubur, East Jakarta, inadequate crossing facilities heighten risks amid intensifying traffic on the Cibubur Alternative Highway. Systematic observations over three days (December 15–17, 2022) revealed peak-hour traffic volumes of 2,860 vehicles and a 32.9% drop in pedestrian crossings due to safety fears. This study designs, develops, and tests an Arduino Mega-based pedestrian crossing aid prototype that uses HC-SR04 ultrasonic sensors to detect pedestrians automatically and control traffic lights without manual buttons. The three-stage architecture includes input processing via distance measurement, Arduino Mega logic for decisions, and LED outputs for signals. Testing confirmed 100% accuracy in detecting objects within 10 inches (25.4 cm) and activating red lights over 50 iterations. This low-cost ($30 USD/unit), open-source solution advances embedded systems for pedestrian safety, offering adaptable traffic management in resource-limited urban areas lacking conventional infrastructure.

INTRODUCTION

Pedestrian safety at road crossings constitutes a critical global public health challenge. According to the World Health Organization (WHO, 2018), road traffic injuries represent the eighth leading cause of death globally, claiming approximately 1.35 million lives annually. Pedestrians comprise 23% of these fatalities, making them one of the most vulnerable road user categories. In low- and middle-income countries, where rapid urbanization often outpaces infrastructure development, pedestrian fatality rates reach disproportionately high levels. The Global Status Report on Road Safety emphasizes that 93% of road traffic deaths occur in countries representing only 60% of the world's registered vehicles, highlighting the critical infrastructure gap in developing urban contexts (Berhanu et al., 2023; Forum, 2016; Rahman, 2025; Sharma & Dehalwar, 2025; Tiwari et al., 2018).

Technological innovations have emerged as promising interventions to address pedestrian safety challenges. In developed countries, smart pedestrian crossing systems employing various sensor technologies—including infrared, ultrasonic, computer vision, and pressure sensors—have demonstrated significant reductions in pedestrian-vehicle conflicts. These systems typically integrate detection mechanisms with traffic signal control to provide demand-responsive crossing opportunities, reducing pedestrian waiting times while maintaining traffic flow efficiency. However, such technologies remain largely inaccessible in developing urban areas due to high implementation costs, technical complexity, and limited local technical capacity for maintenance and adaptation (Adenle et al., 2015; Balogun et al., 2020; Ruth & Coelho, 2015; Umar et al., 2021; Yang et al., 2021).

Along with the rapid development of residential areas in the eastern part of Cibubur, such as the Cibubur Tourism City Complex and the Cibubur Tourism Legend Complex, traffic conditions on the Cibubur Alternative Highway have become increasingly congested. This congestion involves both two-wheeled and four-wheeled vehicles and occurs almost every day, especially during peak hours in the morning and late afternoon after working hours. Under these conditions, pedestrians experience significant difficulties when attempting to cross the road, primarily due to the absence of pedestrian crossing lights and zebra crossings, which poses safety risks (Bella & Silvestri, 2015; Dąbrowska-Loranc et al., 2021; Machingaidze, 2021; Ojo et al., 2019; Zakrzewska-Półtorak & Szulc, 2021).

To understand these conditions, observations were conducted over a three-day period, with observation times scheduled from 06:30 to 08:20 WIB in the morning and from 16:00 to 17:30 WIB in the afternoon. On Friday, December 15, 2022, the observation results showed that the morning traffic volume consisted of 1,026 cars (35.7%) and 1,834 motorcycles (64.3%), with 85 pedestrians crossing the road. In the afternoon, the traffic volume increased by 16.2% for cars and 10.6% for motorcycles, while the number of pedestrians crossing the road decreased by 32.9%.

Observations on Saturday, December 16, 2022, revealed different patterns. In the morning, the car volume reached 1,321 units (59%), while in the afternoon it decreased to 773 units (40.7%). The motorcycle volume in the morning was recorded at 1,125 units (59.2%). The number of pedestrians crossing the road was 38 in the morning and declined to 26 in the afternoon. Overall, from morning to afternoon, the car volume decreased by 16%, the motorcycle volume by 15%, and pedestrian crossings by 31.6%.

On Sunday, December 17, 2022, the morning observation showed a car volume of 898 units (42.8%) and a motorcycle volume of 1,197 units (57.2%). In the afternoon, the car volume decreased to 721 units (41.4%), while the motorcycle volume reached 1,018 units (58.6%). The number of pedestrians crossing the road was 21 in the morning, with an afternoon decrease of 18.8% in car volume, 15% in motorcycle volume, and 24% in pedestrian crossings. These observation results highlight the need for supporting facilities to address pedestrian crossing safety issues effectively (Ahmed et al., 2021; Blackburn et al., 2018; Mukherjee & Saha, 2022; Organization, 2023; Patel, 2020).

Driven by advancements in intelligent transportation systems, extensive international research has explored automated pedestrian detection. For instance, Zhang et al. (2019) developed a computer vision-based system in Beijing with 94.7% accuracy, while Kumar and Sharma (2020) implemented an IoT-enabled solution in New Delhi, reducing pedestrian wait times. Domestically in Indonesia, researchers like Wijaya and Santoso (2021) and Pratama et al. (2022) have created prototypes using infrared and ultrasonic sensors, respectively. However, these studies reveal persistent gaps, including a focus on expensive, complex technologies illsuited for the mixed-traffic environments and resource constraints common in many Southeast Asian cities.

This research addresses these gaps by developing a novel prototype with several key distinctions. First, it utilizes HC-SR04 ultrasonic sensors for their cost-effectiveness, environmental robustness, and consistent performance in variable tropical conditions, unlike previous systems reliant on infrared or camera-based detection. Second, it features contactless, proximity-based automatic activation, eliminating manual buttons to improve hygiene and accessibility. The system is built around the Arduino Mega 2560 microcontroller, selected for its extensive I/O capabilities, programming memory, low cost, and strong open-source community support—factors enhancing scalability and maintenance in developing markets.

The design prioritizes contextual appropriateness for implementation in areas like Cibubur, where conventional pedestrian infrastructure is lacking but basic power exists. By combining affordable ultrasonic sensors, an accessible Arduino platform, and automatic operation, this prototype offers a technologically appropriate solution aimed at rapid deployment without extensive civil work, directly addressing the identified research gaps concerning cost, complexity, and environmental suitability.

Based on these conditions, the research proposes the development of a prototype to facilitate pedestrian crossings. The proposed tool is designed to detect hand movements or object presence using sensors, which are then processed by an Arduino Mega microcontroller to automatically activate pedestrian crossing lights without requiring pedestrians to press a manual button, thereby improving convenience and safety.

The expected technical specifications include an adjustable detection range of 10–50 inches, a response time under one second, and operation within a 0–50°C temperature range. This research is particularly urgent due to Cibubur's rapid urbanization, increasing pedestrian fatalities, post-pandemic mobility patterns intensifying vehicle-pedestrian conflicts, and the current maturity of affordable sensor technologies. The anticipated benefits are both theoretical and practical: theoretically, it contributes to embedded systems and pedestrian behavior literature; practically, it offers municipal governments a replicable, low-cost safety solution for rapid deployment. It also serves as an accessible educational platform and an open-source model for community-led infrastructure initiatives, with subsequent sections detailing the methodology, results, and implementation recommendations.

METHOD

This research employs a design science methodology, which combines engineering design processes with scientific validation protocols. The development followed a five-phase approach: (1) requirements specification based on observational data, (2) system architecture design, (3) prototype fabrication and assembly, (4) software programming and logic implementation, and (5) functional testing and validation.

The hardware used in making the project is as follows:

1. Arduino Mega 2560 as a microcontroller development board based on Arduino using the ATmega2560 chip.
2. Ultrasonic Sensor HC-RS 04 as a tool that functions as a transmitter, receiver, and controller of ultrasonic waves.

3. Jumper cable is an electrical cable that has connector pins at each end and allows two components to be connected.
4. light-emitting diode as a semiconductor that emits one color of light in the form of electromagnetic light when given a forward voltage.
5. Using cardboard

The software used in this project is as follows:

1. Arduino IDE is a programming application for commands that will give microcontroller.

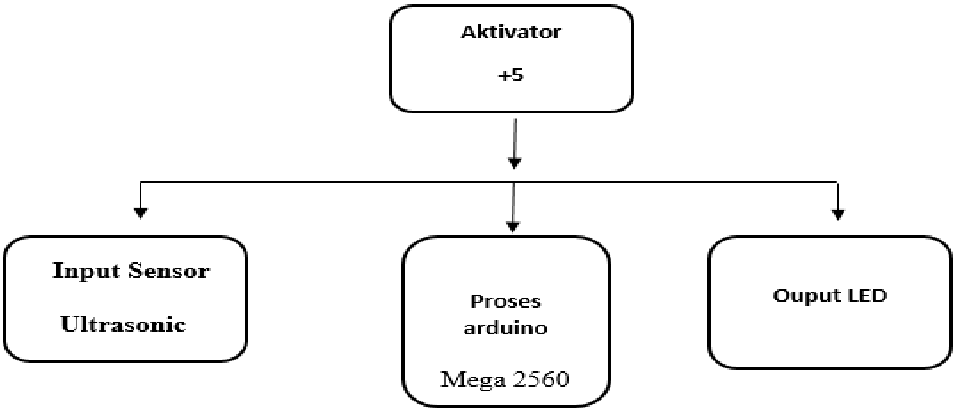


Figure 1. Block Diagram Analysis

The design circuit for this Arduino Mega-based road crossing aid can be divided into three block diagrams: Input, Process, and Output. The Input block describes the input for the microcontroller and its input media. The Process block describes the processing obtained from the input to obtain the appropriate output, while the Output block describes the resulting output and its output media. The block diagram can be seen.

RESULTS AND DISCUSSIONS

Data development of the housing complex area in the eastern part of Cibubur such as the Cibubur Tourism City Complex and the Cibubur Tourism Legend Complex, causing traffic on the Cibubur Alternative Highway to be quite dense, both 2-wheeled and 4-wheeled vehicles every day, especially during working hours and after work with this condition, especially for pedestrians who want to cross, they experience difficulties, because there are no crossing lights and there is no zebra crossing.

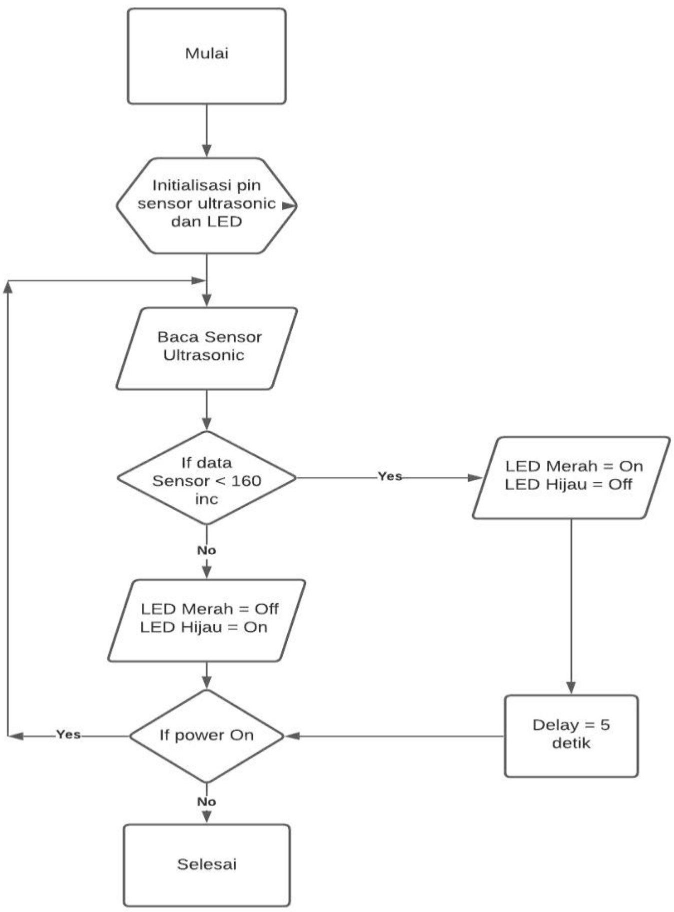


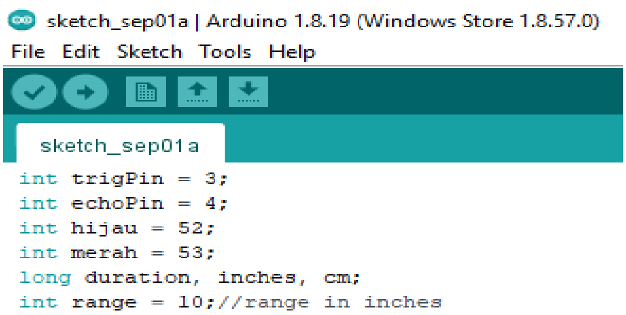
Figure 2. Flowchart

Flowchart diagrams illustrate existing conditions and processes, from initial processing to completion. Step-by-step procedures are essential to ensure the tool functions as intended. The flowchart begins with a "Start" symbol, indicating the tool is ready for use. Program initiation follows, reading all components. It then checks the condition: if the distance is 10 inches or less, the LED changes from green to red. If the distance exceeds 10 inches, the sensor repeats the reading until the condition is met.

Program Analysis

1. In the Program Analysis, the Author will explain the program listing that was created.

   To explain the condition of the tool that has been created. Output Explanation. Initialize the variables of the Ultrasonic Sensor and LED pins and set the distance limit in inches.



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File Edit Sketch Tools Help

sketch_sep01a

```
int trigPin = 3;
int echoPin = 4;
int hijau = 52;
int merah = 53;
long duration, inches, cm;
int range = 10;//range in inches
```

Figure 3. Ultrasonic Sensor and LED pins

2. The void setup function is used to run the Arduino program only once. It defines the variables for the ultrasonic sensor pins and LED.

```
svoid setup() {
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode (hijau, OUTPUT);
  pinMode (merah, OUTPUT);
  digitalWrite(hijau, HIGH);
}
```

Figure 4. Ultrasonic Sensor and LED pins

3. Void loop is used to run the program repeatedly to determine how long the *trigger pin and echo* pin are on and to call.

```
void loop() {
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(5);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);
  inches = microsecondsToInches(duration);
  cm = microsecondsToCentimeters(duration);
```

Figure 5. Ultrasonic Sensor and LED pins

4. The condition where if the value of the inch variable is less than 10, it will turn on the red light and then turn off the green light.

```
 if (inches < 10) {
  digitalWrite(merah, HIGH);
  digitalWrite(hijau, LOW);
  delay(20000);
}
```

Figure 6. Ultrasonic Sensor and LED pins

5. If the value of the inch variable is not less than 10 then it will turn off the red light and then turn on the green light.

```
 }
  else {
   digitalWrite(merah, LOW);
   digitalWrite(hijau, HIGH);
 }
}
```

Figure 7. Ultrasonic Sensor and LED pins

6. Function to convert from ultrasonic sensor to inch and cm units.

Tool Installation

Install each component on the Arduino Mega 2560. Each component will be connected using jumpers. The following explains the installation steps:

1. Ultrasonic Sensor:
   a. The VCC leg is connected to the 5V pin
   b. *Echo* leg is connected to pin 4
   c. *Trigger* leg is connected to pin 3
   d. The GND leg is connected to the GND pin
2. The positive leg of the Red LED is connected to pin 53
3. The positive leg of the Green LED is connected to pin 52
4. Each ground on the component is connected together and connected to the GND pin.

After everything is installed, the Arduino Mega is connected using an adapter. Install each component on the Arduino Mega 2560. Each component will be connected using jumpers. The following explains the installation steps:

Tool Operator

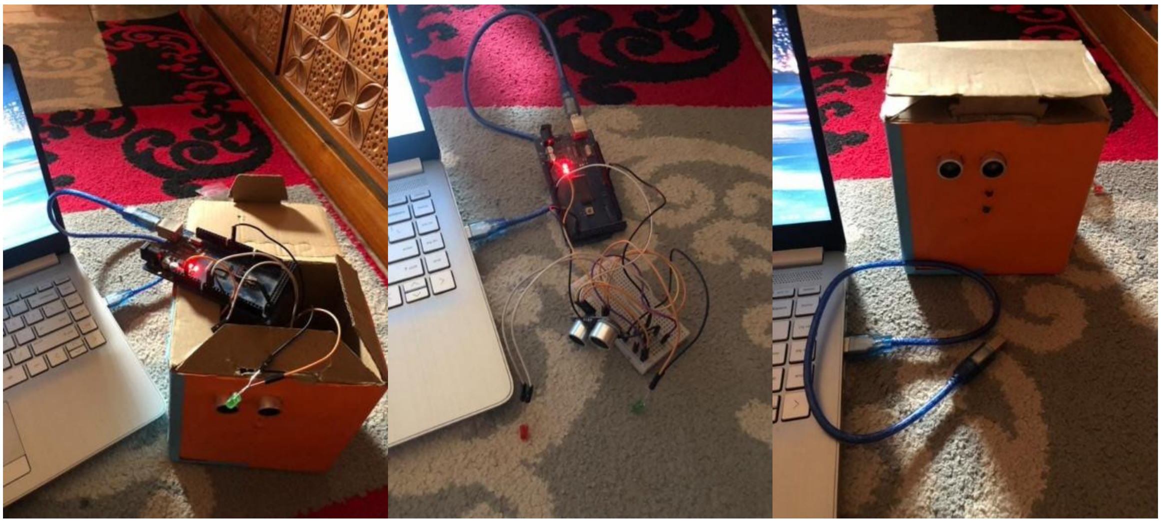

Figure 8. Tool Operator

The Arduino Mega's power supply is obtained through an adapter or *power bank.* The Arduino Mega will initialize the pins of the components used and read the entire program. Once the Arduino Mega is activated, all components will power on automatically. Once all the components and tools are ready, all we have to do is wait. Once an object is detected approaching within 10 inches, the red light will illuminate.

CONCLUSION

Based on the activities that have been carried out during the development of the system using a prototype model on the mapping information system for the potential of the Ardoino Mega-based crossing aid, it has been successful and obtained a prototype model of the mapping information system that uses common database queries and operations. The entire prototype built has gone through a development period from development to testing. During the development period to functional testing of the system interface. The satisfaction level of the prototype stage is Agree and Disagree. Then the results of testing on the development of the mapping system on the Cibubur Alternative Road, East Jakarta district. For future research, integrating real-time GIS data and machine learning for predictive traffic analysis could enhance accuracy and scalability in dynamic urban environments.

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