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**Article**

# Design System of Solar-Powered Safety Lamp Integrated Proximity Sensor as a Solution for Accident Prevention at Blind Spot Areas

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**Abstract:** The curved contour of the road creates blind spots which increase the risk of traffic accidents. Throughout 2019, there were 107,500 accident cases recorded in Indonesia. Therefore, efforts are needed to provide road infrastructure that supports driving safety, such as traffic signs to reduce the risk of accidents in blind spot areas. This research aims to design a smart safety light warning system that is integrated with solar-based street lighting. The design uses a design-based research approach referring to several established standards including Indonesia National Standard (SNI) 7931: 2008, SNI IEC 60529:2014, Regulation of the Minister of Transportation of the Republic of Indonesia Number PM 13 of 2014, Manual on Uniform Traffic Control Devices (MUTCD) issued by the Federal Highway Administration (FHWA) of the United States Department of Transportation (USDOT), and Article 115 of Minister of Transportation Republic of Indonesia Regulation PM 27 of 2018. This study used Design-Based Research (DBR) as a research methodology. The result of this study is a prototype design and development of smart safety light warning system which can be optimized. Validation of the design and circuit is conducted using prototyping modeling 1:20 from the original dimensions to measure the function and performance of the circuit. The prototype is capable of turning on warning lights and siren notifications when detecting objects with a maximum distance of 350 cm as measured by the HC – SR04 sensor. Charging the stored solar panels via the accumulator allows the technology to continue working for 45 hours without charging. For power efficiency purposes, the technology is equipped with an LDR (Light Dependent Resistor) sensor with a minimum limit of 341-lux which regulates the lighting. The development of these safety lights will increase driver awareness when passing through blind spot areas and have positive implications for reducing the number of accidents in Indonesia.

**Keywords:** Blind Spot, LED, Safety Light Technology, Traffic Sign, Solar Energy.

## 1. Introduction

Transportation is an essential necessity for society, as its significance is intrinsically linked to the ever-growing need for mobility within communities [1]. The need for transportation can be seen from the increasing number of motorized vehicles to this day [2-3]. According to data from the Central Bureau of Statistics, the number of motorized vehicles in Indonesia in 2020 reached 141,992,573 units [4]. The largest contribution was the number of motorcycles with a total of 120,042,298 units in 2019. The second largest contribution is passenger cars with a total of 16,413,348 units.

This increase in the number of vehicles must be accompanied by the provision of road infrastructure that supports driving safety and safety riding. One of the enabling behavioral factors in driving safety is the provision of facilities or infrastructure for safe driving behavior, such as providing traffic signs and street lighting [5-6]. Providing road lighting will make it easier for drivers to drive and riders to ride, especially in hilly areas and areas with poor lighting. The better provision of facilities to support driving safety will minimize the risk of accidents on the road [7].

On the other hand, Indonesia is a country with a land area of 1,913,578 $Km^2$ [8]. The vast territory means that Indonesia has abundant natural resources. One of the greatest potential sources in Indonesia is solar heat. Indonesia's geographical location on the equator means that Indonesia can receive solar heat throughout the year, this makes the potential for utilizing solar heat as new and renewable energy easy to implement [9]. Solar panel technology can be applied to support the provision of lighting facilities on highways. This can help the transformation of clean and affordable energy following the 2030 sustainable development goals [10].

In addition, Indonesia's diverse and winding geographical location or environmental conditions and road conditions often cause traffic accidents [11-12], these accidents involving small to large vehicles, causing losses. The number of traffic accidents in Indonesia, which has increased every year, has an impact on the increase in population deaths [13-14]. Traffic accidents in Indonesia increase every year. There were 107,500 traffic accidents in 2019, up from 103,672 in the previous year 2018 [15-16]. Based on the background, there needs to be synergy between all parties so that the number of accidents that occur due to curved road contours can be reduced significantly. Public awareness of driving and traffic is the main factor in reducing the number of traffic accidents [17-18]. Road traffic accidents are still a major problem in Indonesia. One of the causes of the high number of accidents is the lack of danger warnings in blind spots or blind spots on sharp corners. In line with this, the application of traffic sign technology using renewable energy and smart controls can be implemented as an innovation to reduce the number of traffic accidents. Therefore, this research was designed to design a warning system based on solar-powered traffic lights connected to distance sensors. This system is designed to alert drivers about potential hazards in blind spots, helping them remain vigilant and slow down to avoid accidents. By implementing this intelligent and continuous warning system, we hope to enhance road safety and prevent accidents.

## 2. Materials and Methods

### 2.1. Methodology

This study used Design-Based Research (DBR) as a research methodology [19-20]. This type of research begins by analyzing the problem and then conducting a literature study regarding smart safety lights based on proximity sensors, determining specifications, and designing tools using Autodesk Inventor. Next, conduct fabrication using a prototyping approach. Prototyping is conducted through experimental investigations, with increased application of the best parameters and increased design performance results. This observation applies to a wide range of studied design problems [21, 22]. Fig. 1 explains the design flow of a smart safety light based on a proximity sensor.

The second stage is the schematic and 3D design stage, this stage is an embodiment of the scheme into a more concrete design. This stage consists of several alternative schemes which are worked out in detail in the form of conceptual designs. At this stage, decision-making is the key to determining the design concept for the product to be developed [23, 24]. The last step in the schematic and 3D design process involves creating a detailed design using computer software to reduce errors. There were three primary challenges in the design process such as developing a sound plan, selecting the optimal solution to implement the design, and assessing alternative designs. To create the software and hardware design, researchers used Jupyter Lab and Autodesk Inventor software because it can generate detailed control systems and 3-dimensional renderings [25].

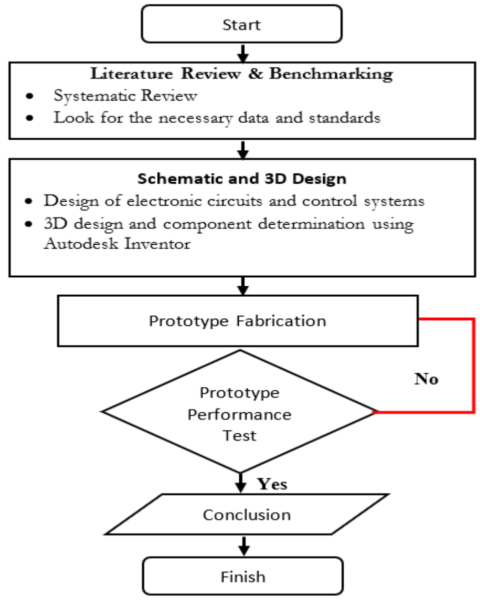


**Figure 1**. Smart safety light design flow diagram.

The next stage is Prototype Fabrication, this stage is to make a prototype at a scale of 1:20. After the prototype is successfully created, testing is conducted to simulate the resulting output and make improvements or evaluations if there is an output that is not appropriate. In the final stage, conclusions are drawn by collecting test result data.

### 2.2. Design

The design of smart safety light poles is integrated with public street lighting. Several types of poles used for street lights are iron poles and octagonal poles. Fig. 2 shows the shape of the pole arm design (ornament handlebar) based on the 2008 SNI 7391 standard [27]. The single ornament handlebar design is suitable for providing lighting on one side of the road compared to double ornament handlebars or without ornaments. Double ornaments are usually suitable for application on roads with a border in the middle, while the sleeveless model is suitable for providing lighting on sidewalks or parks. Therefore, in this research, the design of a smart safety lamp post uses a single ornament handlebar model.

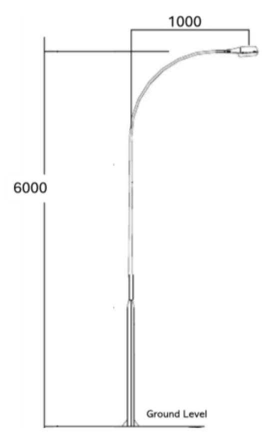


**Figure 2**. Standard street light arm shape (Source: SNI 7931: 2008 [27]).

For directing the lighting towards the center or middle of the road, the angle of the ornament's handlebars is adjusted using (1) and (2).

$$T = \sqrt{h^2 + c^2} \quad (1)$$

So:

$$\text{Cos } \alpha = \frac{h}{t} \quad (2)$$

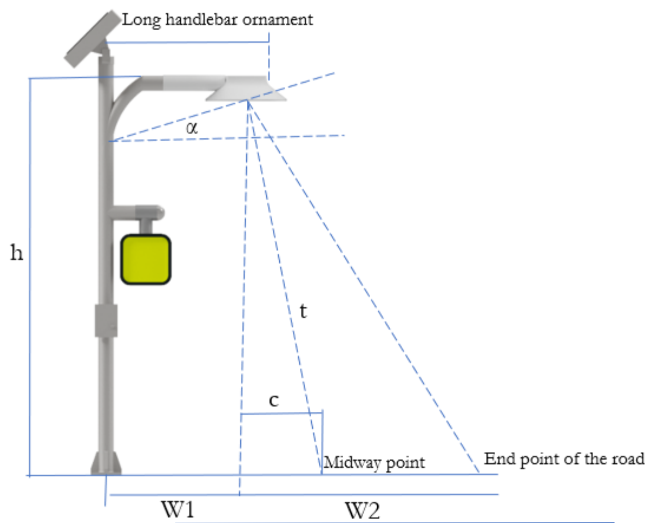


**Figure 3.** Determining the angle of ornament handlebars' inclination relative to the road width (Source: SNI 7931: 2008 [27]).

In Fig. 3:
h: pole height
t: distance from the lights to the middle of the road
c: horizontal distance of the center of the roadway
W1: pole to the end of the lamp
W2: the horizontal distance of the light to the end of road

The octagonal pole height was designed to be 6 meters with an ornamental handlebar length of 1 meter. A visualization of the design for determining the angle of inclination of the ornament's handlebars relative to the road width can be seen in Fig. 3. These dimensions were selected based on the SNI 7931: 2008 standard and the average height of local street lighting lamps [27]. The angle of the handlebar ornament decreases as the pole height increases, resulting in more diffuse light. Therefore, (3) is used to calculate the slope of the handlebar ornament based on (1) and (2). That is to say

$T = \sqrt{6^2 + 5^2}$ = 7.81meter
So,
$\text{Cos } \alpha = \frac{h}{t}$
$\text{Cos } \alpha = \frac{7}{7.81}$ = 0.896
$\alpha = \cos^{-1} 0.896$ = 26.363°

Then, an ornamental handlebar tilt of 26.323°.

### 2.3. Tools and Material

The tools (both hardware and software) used in research on designing smart safety lights based on proximity sensors are as follows:

1) Arduino UNO R3, functions as a hardware controller. Solar panel, function as a converter of solar energy into electrical energy using the principle of the photovoltaic effect.
2) Battery, functions to store electrical energy from solar panel.
3) SC (Solar Controller), functions as a voltage and current regulator that flows from the solar panel to the battery to prevent overvoltage or overcharging.
4) Grid electricity, functions as a backup power source when the battery voltage falls below the threshold set in the program.
5) AC/DC Converter, functions to change the AC source to 12-volt DC because the LED lights used have such working specifications.
6) Deep Cycle Battery, functions as an electrical energy store. The deep cycle type was chosen because this type of battery has a more stable discharge and is slower in storing electric current. This type of battery can be used until the electric current runs out and then charged again.
7) Relay, the use of two relays functions as a power source selector switch and controls the turning on and off of the lights.
8) The millimeter functions to inspect the voltage and current when testing solar panels
9) Proximity sensor, functions as a detector for vehicles around the safety light installation point. This sensor is installed on a pole 1.5 m from the ground.
10) LDR (Light Dependent Resistor) sensor, functions as a light detector which is used to observe the brightness in the environment at the installation point. The brightness level of the environment will be a parameter for turning the lights on and off. If the LDR output shows a dark indication with previously set parameters, the light will turn on.
11) LED Driver, this circuit functions to regulate the voltage output of the lamp power source which will affect the brightness of the lamp flame.
12) Current sensor, this module functions to determine the current flowing in the LED lamp. If a current value is detected greater than 0.01 mA, then the lamp is on.
13) LED lights, function as a source of lighting for safety lights. The LED type was chosen because it is more energy efficient and because the brightness level can be adjusted.
14) Computer that has Autodesk Inventor, Fritzing, and Arduino IDE software installed.

### 2.4. Performance Test

The smart street light prototype underwent a day-long testing to compare its energy usage with estimated calculations. In addition to testing the integration function, various other measurements were conducted independently to assess the tools' maximum performance. There were five instruments in the test, Table 1 shows the test indicators of the smart safety light prototype. In the actual conditions during testing, the test results for the entire instrument met expectations.

**Table 1**. Prototype testing.

| Test Instrument | Test Scenarios | Expected Results | Result | |
|---|---|---|---|---|
| | | | Yes | No |
| Function of Street Lighting with Integrated LDR Sensor | LED is off: If the light intensity detected by the LDR sensor is > 20 | LED Off | ✓ | |
| | LED is on: If the light intensity detected by the LDR sensor is < 20 | LED On | ✓ | |
| Detecting Objects | The proximity sensor detects objects at a distance of <15 cm | The sensor is able to detect objects, the buzzer and warning lamp turn on | ✓ | |
| | The proximity sensor detects objects at a distance of >15 cm | The sensor is able to detect objects, the buzzer and warning lamp do not turn on | ✓ | |
| Warning Lamp | The Warning Lamp lights up when the proximity sensor detects an object | Warning Lamp On | ✓ | |
| Buzzer | The buzzer lights up when the proximity sensor detects an object | Buzzer On | ✓ | |

### 2.5. Estimated Energy and Usage on Device

Smart street light uses a solar panel and a battery as the main energy source. This concept will certainly cut the cost of local government electricity bills. However, this resource is very dependent on the availability of sunlight. The hotter and brighter the weather, the better the battery charging speed. On the other hand, when it is cloudy or rainy, the solar panel will produce very little electricity which results in the battery not being fully charged. Based on the specifications of the equipment used, the total load of smart safety lights is:

Street light usage load = Number of lights x Power x Usage Time
= 1 lamp x 30 Watts x 12 hours
= 360 Wh

LED panel usage load = Number of LED x LED Power x Usage Time
= 1 LED panel x 30 Watts x 3 hours
= 90 Wh

Siren usage load = Number of Siren x Siren Power x Duration of Use
= 1 Siren x 120 Watts x 3 hours
= 360 Wh

Total usage = Street light load + LED load + siren load
= 360 Wh + 90 Wh + 360 Wh
= 840 Wh

Total Usage Load 840 Wh per day or 35 W per hours.

Capacity Battery = 12 V 120 Ah

Battery Power = Battery Voltage x Battery Capacity
= 12 V × 120 Ah
= 1440 Wh

Battery working life = Battery Capacity / Total Usage Load
= 1440 Wh / 840 Wh
= 1.714 day
= 1 day, 17 hours, 8 minutes and 10 seconds.

Based on the calculations that have been conducted, the power generated and stored in the battery can be used for 1.714 days, meaning that the battery power is more than enough to supply electrical energy needs in one day or 24 hours.

The electricity generated by a 300 Watts solar panel amounts to 300 Watts when the panel receives maximum solar energy during peak hours in sunny conditions. In one day, the total energy produced by a solar panel is 300 Watts multiplied by 5 hours (peak sun hours), resulting in 1500 Wh. Consequently, the electrical energy produced by a solar panel exceeds the electrical energy released by the battery, allowing for maximum battery charging.

The energy usage of the device within 24 hours (1 day) is 840 Wh. So, 840 Wh is the total load of this device per day. The remaining energy produced by a solar panel is stored for the battery charger with a total of remaining energy: 1500 Wh – 840 Wh = 660 Wh. Based on this, 660 Wh is the remaining energy that will be saved in the battery.

## 3. Result and Discussion

### 3.1. Smart Safety Light Technology Concept

Smart Safety Light Technology with an implementation plan as in Fig. 4, aims to connect two traffic warning sign units to provide information in blind areas. This can be achieved through the use of solar photovoltaic or solar panel to power the electrical system and store it in an accumulator or battery. In case the battery capacity is almost empty, the system will automatically switch to resources from the electrical grid. The warning light can activate the LED lights on the warning signs and produce a siren sound when a vehicle is approaching, thanks to the proximity sensor installed in the Safety Light unit. The sensor works by detecting the presence of vehicles passing on both sides of the road, which helps drivers increase alertness and reduce vehicle speed, especially in areas with blind spots. According to the Regulation of the Minister of Transportation of the Republic of Indonesia Number PM 13 of 2014, the placement of a safety lamp integrated with a proximity sensor should be conducted at a minimum distance of 80 meters from the turning point, assuming a maximum vehicle speed of 60 km/hour when turning [28].

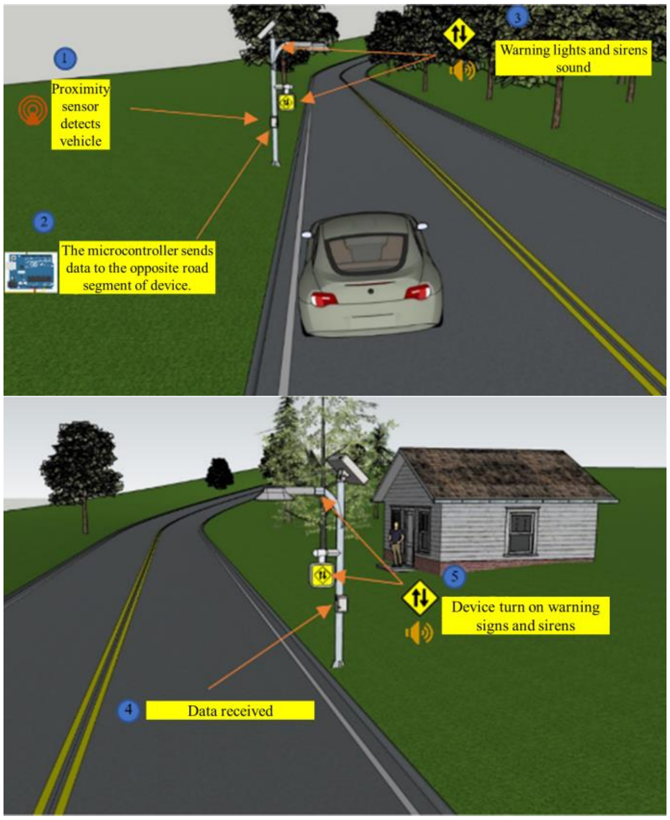


**Figure 4.** Implementation concept plan of smart safety light technology concept.

### 3.2. Components and Standardization

To ensure the safety and durability of electronic installations, it is important to protect them from water damage. This helps to increase the quality of the product and prolong its service life. The International Protection (IP) standard IEC 60529: 2014 regulates the water resistance of electronic components. This standard is currently included in the enclosure or body covering of an electrical system with the number SNI IEC 60529:2014 [29]. Component selection and sizing must also consider two other standards, including:

*3.2.1. MUTCD (Manual on Uniform Traffic Control Devices)*

Based on the road equipment guidelines from MUTCD, the time required to see and react to a sign is the sum of the time required for perception, motion identification and execution, called PIEV time. PIEV time can vary from a few seconds for general signs to 6 seconds or more for warning signs installed on highways depending on the physical and mental condition of road users.

*3.2.2. Regulation from Minister of Transportation of the Republic of Indonesia No PM 13 of 2014 [28].*

This regulation sets minimum standards for the use of signs, placement, types, and symbols on signs as well as other regulations related to traffic safety. Sign models and sign dimensions are designed according to standards set by the Ministry of Transportation in Minister of Transportation Regulation Number PM 13 of 2014, as shown in Fig. 5.

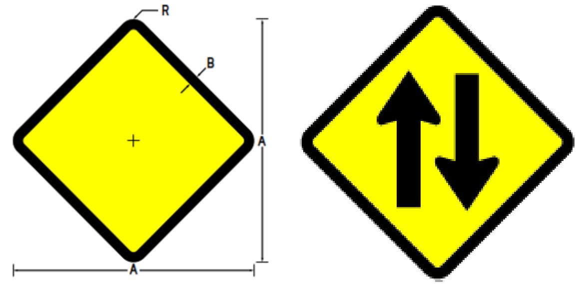


**Figure 5**. Dimensions of warning signs (source: republic of Indonesia minister of transportation regulation no. PM 13, 2014 [28]).

Furthermore, the size of the warning lamp must at least have the qualifications as shown in Table 2 [28].

**Table 2.** Size standard of warning sign (mm) based on regulation of the minister of transportation of the republic of Indonesia No. PM 13 of 2014.

| Size Type | A | B | R |
|---|---|---|---|
| Small | 450 | 25 | 37 |
| Medium | 600 | 25 | 37 |
| Large | 750 | 31 | 47 |
| Very Large | 900 | 38 | 56 |

Smart safety light consists of seven main constituent components, as shown in Table 3. The three-dimensional rendering design of the smart safety light can be seen in Fig. 6.


**Figure 6**. Smart safety light technology design based on proximity sensor.

**Table 3**. Information detail parts.

| Number | Part |
|---|---|
| 1 | Light Pole |
| 2 | Lighting |
| 3 | Accumulator |
| 4 | Solar Panel |
| 5 | Horn |
| 6 | Warning Lamp |
| 7 | Electrical Panel Box |

In Fig. 6, number 1 is a support pole made of steel pipe with a diameter of 76.2 millimeters and a thickness of 3 millimeters which has been galvanized. The use of this material is based on the requirement of a service life of 20 years as determined by Article 115 of Minister of Transportation Regulation PM 27 of 2018 [27]. Galvanized steel is an efficient material because it has an estimated material life of up to 32 years with good corrosion resistance (Marcell, 2021), and has material toughness of tensile strength values reaching 510 – 600 MPa. Smart safety lights are equipped with main lights (Fig. 6 number 2) as road lighting and 300-lux LED lights as warning lamps (Fig. 6 number 6). The main lights use high-pressure sodium lamps because they have efficiency and a service life of up to 25,000 hours of operation. This value is relatively longer compared to mercury lamps or metal halide lamps. The next component is the accumulator (Fig. 6 number 3). The selection of accumulator specifications must be adjusted to the minimum limit with a charging capacity (volt-ampere hour) that is at least capable of providing electrical energy reserves to light the lights for three consecutive nights or 36-hours of operation without any electric current. The accumulator design at the top aims to prevent theft. Battery age must also consider a minimum service life of 3 years. Next is the solar panel component (Fig. 6 number 4) which has the 3 units of 100 Wp monocrystalline type. Monocrystalline solar panels are used because they are more effective in producing energy than polycrystalline types even in shady situations [26]. The next component is the buzzer which is shown in Fig. 6 number 5. The buzzer is a notification to the driver, then it must be able to be used outdoors with specifications ranging from 87–110 dB. The final component is the panel box which contains the electronic sensor circuit and electronic installation of the solar panel (Fig. 6 number 7). Further specifications of smart safety lights can be seen in Table 4.

**Table 4**. Smart safety light technology specifications.

| No | Part | Description |
|---|---|---|
| 1 | Safety Lamp Frame | 3" thick 3 mm stainless steel galvanized pipe |
| 2 | Safety Lamp Dimensions | Pipe Diameter 3", Width 2.5 m, Height = 4 m |
| 3 | Microcontroller | Arduino Uno R3 |
| 4 | Proximity Sensor | Autonics BJ10M-TDT Photoelectric Sensor<br>10-meters Sensor Range and 5 seconds Delay Time |
| 5 | Light Sensor | LDR Sensor |
| 6 | Speaker output | Siren Mini Motor Siren MS-190 MS190 220VAC 12VDC 24VDC Iterno - 12VDC 120Watt 110 dB |
| 7 | Electrical wiring system | Cable installation underground |
| 8 | Warning Light Type | LED Panel 300 LUX |
| 9 | Lighting Lamp | 90 Watt |
| 10 | Power Input Type | Monocrystalline Solar Panel 100 Wp Quantity: 3 units |

### 3.3. Electronic Circuit Design

The Safety Lamp uses electronic components as a control system that works to increase road user awareness in blind spot areas. The components used are a Proximity Sensor HC – SR04, an alarm buzzer, and an LDR sensor. The control design is programmed using the Arduino Uno R3 microcontroller via Arduino Ide software with the C programming language. In program design, the initial step taken is to declare all the components used in the safety lamp system, namely by initializing the component declaration, then continuing with programming the function of the electronic components using adjusted based on the basic scheme of the system. Programming component functions are conducted sequentially by placing the component pin sequence. Furthermore, the electrical and electronic circuits of the distance sensor safety light technology integrated into the designed concept can be seen in Fig. 7.

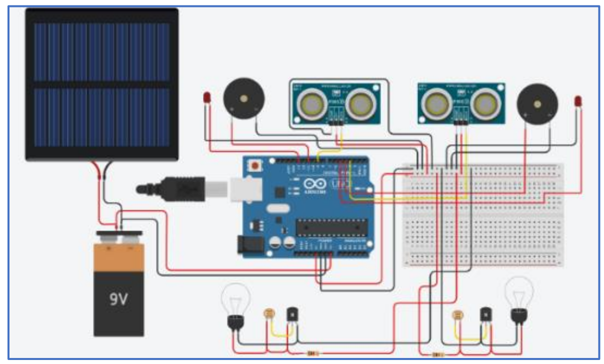


**Figure 7**. Electrical and electronic circuits of device.

### 3.4. Prototype Programming

The Arduino UNO microcontroller is programmed using the Arduino IDE software to conduct the working principles of the prototype. The program syntax uses a const integer data type to define the pins used by the Arduino UNO microcontroller. Repeated commands are instructed with the "delaymicroseconds" command to avoid delays in sending and processing data by the microcontroller. This delay must be avoided when the ultrasonic sensor detects an object. Thus, the buzzer and warning light can immediately turn on. The program syntax display of the prototype can be seen in Fig. 8.

```
CODING_PROTOTYPE_JR_ROVATION_2022.ino

void setup() {
pinMode(trigPin1, OUTPUT);
pinMode(echoPin1, INPUT);
pinMode(buzzer1, OUTPUT);
pinMode(ledPin1, OUTPUT);
pinMode(trigPin2, OUTPUT);
pinMode(echoPin2, INPUT);
pinMode(buzzer2, OUTPUT);
pinMode(ledPin2, OUTPUT);
Serial.begin(9600);
}


void loop() {
// Clears the trigPin
digitalWrite(trigPin1, LOW);
delayMicroseconds(2);
digitalWrite(trigPin1, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin1, LOW);
duration1 = pulseIn(echoPin1, HIGH);
distance1 = duration1*0.034/2;

digitalWrite(trigPin2, LOW);
delayMicroseconds(2);
digitalWrite(trigPin2, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin2, LOW);
duration2 = pulseIn(echoPin2, HIGH);
distance2 = duration2*0.034/2;
```

**Figure 8**. Syntax Program using Arduino UNO.

Then, the device working system scenario can be seen in Fig. 9.

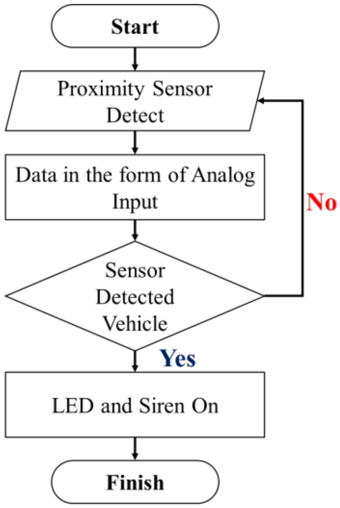


**Figure 9**. Device work system scenario.

Based on the flowchart in Fig. 9, which shows the device work system scenario, the following explanations are provided:

a. The proximity sensor detects the distance of the vehicle that will pass in the blind spot lane and then sends the distance detection data to the Arduino Uno R3 microcontroller. The data sent by the proximity sensor is analog data.
b. The data read by the Arduino Uno R3 microcontroller is then used to light the LED panel to display warning signs to reduce speed due to passing in blind spots.
c. When a vehicle passes, the LED panel will light up and activate the siren. The siren will sound for a specific duration that has been previously set. The purpose of the siren is to alert others that a vehicle is passing.
d. The device works by repeating its step scenarios automatically. Its main principle is to detect the distance of vehicles, and then activate LED warning signs and sirens in highway blind spot areas. This effort aims to reduce the risk of traffic accidents by providing additional warning signals.

### 3.5. LDR and Ultrasonic Testing

Fig. 10 is a prototype device that has been successfully created to test an electronic circuit consisting of sensors and technology functions. The prototype has been made in a 1:20 ratio to evaluate the design concept and electronic functionality of the device. It has been created using electronic components and materials that resemble the original design plans, but in a smaller size. Several tests and simulations have been conducted on the prototype to ensure that the proximity sensor, lights, and other components function properly according to the proposed concept. The purpose of this prototype is to support accident prevention solutions in blind spot areas. The results of the prototype testing will be used to refine the design and create Safety Lights that are of actual size and shape.

**Figure 10**. Smart safety light prototype.

Then, the Light Dependent Resistor (LDR) sensor undergoes testing to determine the accuracy of the light intensity detected by the sensor. This will provide control parameters when the light is on. The test was conducted by using a 1076 lux flashlight aimed at the LDR sensor, while the distance was measured using a ruler. The light intensity was measured using a lux meter. The results of the LDR sensor test are available in Table 5.

**Table 5**. LDR sensor testing.

| No | Lighting Distance to Sensor (cm) | Light Intensity | Headlight Performance |
|---|---|---|---|
| 1 | 5 | 935 | Lights off |
| 2 | 10 | 802 | Lights off |
| 3 | 15 | 632 | Lights off |
| 4 | 20 | 441 | Lights off |
| 5 | 25 | 300 | Lights On |
| 6 | 30 | 221 | Lights On |
| 7 | 35 | 178 | Lights On |
| 8 | 40 | 97 | Lights On |
| 9 | 45 | 32 | Lights On |
| 10 | 50 | 4 | Lights On |

In evaluating the ultrasonic sensor's performance, its responsiveness to approaching objects is assessed. Upon reaching a certain distance, the program triggers the buzzer to emit a loud signal for the user. Based on the results in Table 6, the functional tests have been completed and the system is operating at optimal levels.

**Table 6**. Ultrasonic sensor testing.

| No | Distance of Object to Sensor (cm) | Buzzer | Ultrasonic Sensor Performance |
|---|---|---|---|
| 1 | 100 | On | Object detected |
| 2 | 150 | On | Object detected |
| 3 | 200 | On | Object detected |
| 4 | 250 | On | Object detected |
| 5 | 300 | On | Object detected |
| 6 | 350 | On | Object detected |
| 7 | 400 | Off | Object not detected |
| 8 | 450 | Off | Object not detected |
| 9 | 500 | Off | Object not detected |
| 10 | 550 | Off | Object not detected |

### 3.6. Stress–strain Analysis

Researchers conducted the stress–strain analysis on the Warning Lamp using Autodesk Inventor Software with the screenshot attached in Fig. 11. This stress analysis is to measure the deformation of the tool or device frame when a static load is applied [30]. Through this analysis, the designer will find out the boundary conditions of the warning lamp.

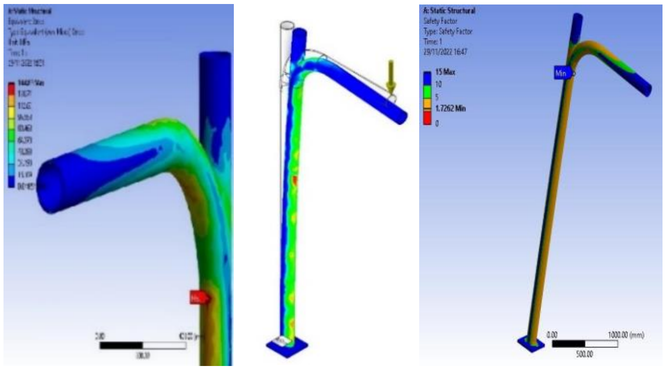

**Figure 11**. Stress–strain analysis of smart safety light.

Based on the analysis conducted in the critical area if static loading is conducted at the end of the lamp. The material used in this traffic lamp frame is Structural Steel ASTM A36. The load used is 12,000 N which is at the side end of the tube in the –Y direction. The Maximum Equivalent Stress value is 144.83 Mpa. The minimum Safety Factor value is 1.7262 which is the location of the part that bears the maximum stress. Based on the detailed analysis, it shows that this Traffic Lamp design can be said to be safe because the minimum safety factor value is still above 1.

## 4. Conclusion

Based on the design system, prototype tests, and analyses conducted on traffic light warning systems technology for accident-prone blind spot areas, data was obtained that this street light technology could be developed to increase driver awareness of potential dangers in blind spots. This is indicated by the driver's braking response and speed reduction when the warning light and siren activation system are working. In addition, the collaboration of smart control of distance sensors and light or siren actuators can realize intelligent solution strategies to mitigate accidents in blind spot areas. The implementation of solar energy in the energy supply of road safety lighting systems is very suitable to support sustainable and environmentally friendly concepts.

In general, smart safety lights can connect two warning sign units in a blind spot area using Arduino Uno R3 with C programming language. The database used as warning control is an object detected using the HC – SR04 sensor. The prototype is capable of turning on warning lights and siren notifications when detecting objects with a maximum distance of 350 cm. A form of warning to increase driver awareness is a 300 Lux LED Panel warning light and 87 – 110 dB Loudspeaker. Safety lights with high pressure sodium lighting are placed 80 meters from the bend point. The lamp post has a height of 6 meters, the length of the ornament arm is 1 meter and the angle of the ornament handlebar is 26.323°. The lamp post material is galvanized steel. The safety light pole design uses a reference base following Indonesian National Standard of SNI 7391 of 2008. The smart safety light operates using 3 units of 100 WP monocrystalline solar panels. The 1500 Wh power energy input in peak conditions (illumination) is stored via a 12 V × 120 Ah accumulator to operate safety lights with an energy power requirement of 840 Wh. Even without charging, the stored power from the accumulator can run the smart safety light for 41 hours. For power efficiency purposes, the lighting control is regulated using an LDR (Light Dependent Resistor) sensor with a minimum environmental lighting limit of 341 lux. If the lighting is below 341 lux, then the lighting will turn on, if the lighting is above 341 lux, then the lighting will turn off.

Furthermore, the commercialization of smart safety lights has the opportunity to reduce the risk of accidents on curved road contours (blind spot areas). The massive application of technology will support the achievement of sustainable development goals (SDGs) on point 7 regarding Clean and affordable energy, and support point 9 regarding infrastructure, industry, and innovation. Moreover, it also supports SDGs point 11 regarding sustainable cities and communities. So, this safety light innovation deserves to continue to be developed and perfected for the benefit of society.

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