Analysis of Easy Use of Traffic Lights Using the Visual Cone Angle Method and Visual Cone Radius

Sugiono[1*], Wisnu Wijayanto Putro[1], Rio Prasetyo Lukodono[1], Nur Muhammad Fathurrahman[1], Rahma Sabilah Nurbi[2], Hari Sudjono[1], Bambang Indrayadi[1]

[1] *Department of Industrial Engineering, Universitas Brawijaya, Malang*
[2] *Department of Mechanical Engineering, Universitas Brawijaya, Malang*
[*]*Corresponding author. Email: sugiono_ub@ub.ac.id*

ABSTRACT
Many countries have problems related to traffic density, which causes severe congestion. This condition is exacerbated by the still high accident rate, and material and immaterial losses are still very high. Based on facts on the ground, in Indonesia, the number of accidents due to traffic lights that are not clearly visible is still very high. The aim of this paper is to provide a visual appearance for traffic lights in urban areas so that they can increase convenience for motorists. The visual display includes the location, position of lights, quality of lights, position between vehicles, and type of crossing being used. Traffic light data was taken by sampling main roads in Malang City, East Java, Indonesia, with three main types of vehicles, namely: trucks, cars, and motorbikes. The methods used to turn on traffic lights are the Visual Cone Angle (VCA) and Visual Cone Radius (VCR) methods. Based on the results of visual measurements of the appearance of existing traffic lights, it was found that the average VCA value for trucks = 26.40, VCA for cars = 34.20, and VCA for motorbikes = 46.30. Meanwhile, the existing VCR value for trucks is = 0.776, car VCR = 0.716, and motorbike VCR = 0.569. Improvements in the placement of traffic lights with standard sizes resulted in an improvement in the average VCA of trucks to 23.7 (changed 10.23%), the average VCA of cars to 29.4 (changed 14.03%), and the average VCA of motorbikes to 38.5 (changed 16.85). Improving the VCA value can increase the driver's ability to see the lights and change their colours clearly, thereby increasing awareness when on the road.

Keywords: *Traffic Light, Visual Cone Angle (VCA), Visual Cone Radius (VCR), Visual Display*

1. INTRODUCTION

City development is strongly influenced by economic growth, which affects the citizen's needs to carry out activities and mobilize. The increase in the movement of urban residents affects the level of traffic congestion in a city. This is due to the high level of population mobilization and the high use of private and public vehicles, causing traffic problems in the city. Malang city is the second-largest city in east java province after Surabaya, and is known as the city of education. Common problems such as traffic jams cannot be avoided due to high density levels. The participation of government agencies in providing infrastructure facilities to support community activities and mobilization is urgently needed so that several institutions work together in making regulations and providing safe and comfortable mobility service facilities to the community.
The roles of the institutions that contribute to supporting community mobility are the ministry of transportation as transportation management, the public works service as a provider of road infrastructure and the police as a law enforcement agency. The ministry of transportation is the implementing element of regional autonomy in the field of transportation which has the main task of carrying out regional government affairs in the field of transportation based on the principle of regional autonomy, especially in the field of transportation, both land and water.
The traffic sector here is tasked with providing procedures related to traffic signalling devices with the aim of creating comfortable driving for the public to avoid traffic accidents. Traffic accidents are events that are difficult to predict when and where they will occur. Accidents cause not only trauma, injury, or disability but also death. Accident cases are difficult to minimize and tend to increase along with the increase in road length and the number of vehicle movements. Traffic accidents are events that occur due to errors in road facilities, the environment, vehicles, and drivers as part of the traffic system, both stand-alone and interrelated. Traffic accidents often occur at intersections,

Y. A. Yusran et al. (eds.), *Proceedings of the 2023 Brawijaya International Conference (BIC 2023)*, Advances in Economics, Business and Management Research 294,
https://doi.org/10.2991/978-94-6463-525-6_37

which are critical areas because they connect roads and are frequent points of traffic accidents. Traffic accidents at intersections pose a significant risk to road users and can have severe consequences. According to the sources provided, intersections are high-risk areas for traffic accidents due to various factors such as traffic congestion, road design, and road user behavior [1].

According to the central statistics agency, the number of traffic accidents is increasing from year to year. The ministry of transportation explained that in 2021, as many as 25,266 people would die in traffic accidents. This number increased by 7.3% compared to the previous year, when 23,529 people died. Then the ministry of transportation continued that the number of vehicles that had accidents was 21,463 units, with motorcycles being the vehicle with the most accidents, amounting to 73%, and followed by goods transportation by 12%.

2. LITERATURE REVIEW

Ergonomics is the science, art, and application of technology to harmonize or balance all the facilities used for activity and rest with human abilities and limitations, both physical and mental, so that the overall quality of life becomes better [2]. The objectives of the application of ergonomics are:

1. Improved physical and mental well-being through efforts to prevent bodily and occupational diseases, reduce physical and mental workload, and seek promotion and job satisfaction.
2. Improving social welfare by improving social quality, managing and regulating an effective work system, and increasing a form of protection for workers both during their productive and unproductive ages.
3. Creating a rational balance between the technical, anthropological, economic, and cultural aspects of each work system carried out.

The focus of ergonomics involves three main components, namely humans, machines, and the environment, which interact with one another. This interaction produces a work system that cannot be separated from one another, known as a work system. In practice, if work becomes safe for workers and work efficiency increases, human welfare will be achieved. The success of the application of ergonomics can be seen in improvements in productivity, efficiency, safety, and the acceptance of the resulting design system (easy, comfortable, etc.) [3]. The application of ergonomics can be done through two approaches, namely:

1. Curative Approach
   The approach taken in a process that is already or is underway.
2. Conceptual Approach
   This approach is known as a systems approach and will be very effective and efficient if carried out at the time of planning.

The standard dimensions of vehicles are of average size, with the length of a motorcycle being 2.2 meters, the length of a car being 4.6 meters, and the length of a truck being 6.7 meters. Meanwhile, the standard dimensions for vehicle width for motorcycles are 0.6 meters; for cars, the width is 2 meters; and for trucks, the width is 2 meters. And finally, the standard dimensions for vehicle height for motorcycles are 1.8 meters, for cars 1.7 meters, and for trucks 2.2 meters.

Traffic signalling devices play a crucial role in ensuring intersection safety and managing traffic flow [4]. They provide clear instructions to drivers, pedestrians, and cyclists, allowing for smooth and orderly movement at intersections. These devices, such as traffic lights and stop signs, help to prevent accidents and reduce the risk of collisions at intersections. By using advanced technologies, traffic control systems can now be more efficient and dynamic, adjusting signal timings based on real-time traffic conditions. This not only helps to alleviate congestion but also improves overall safety. By analysing traffic data and utilizing smart transportation systems, signalized intersections can enhance their performance [5]. Using techniques like signal timing optimization and queue analyses, the efficiency of traffic signal control can be improved at intersections. Additionally, the use of traffic cameras and image processing technology can aid in monitoring and managing traffic density at intersections. This approach allows for a more responsive and adaptive traffic control system that can effectively handle varying traffic volumes and minimize delays. By implementing these advancements in traffic control, we can create problem-less and peaceful driving conditions for the public, reducing accidents and promoting a pollution-less life. Furthermore, with increasing population growth and vehicle count in urban areas, traffic congestion has become a pressing issue. Implementing effective traffic signal control systems can help alleviate congestion and reduce the negative impacts of traffic, such as air and noise pollution. It is important to prioritize safety and mobility in traffic control systems, considering the needs of individual operators as well.

The traffic signalling device (APILL) is lamps that control the flow of traffic and are installed at road intersections, pedestrian crossings (zebra crossings), and other places of traffic flow. Traffic lights become a tool that gives a sign when the vehicle must stop and when the vehicle must take turns from various directions [6]. Traffic control at road junctions is intended to regulate the speed of vehicles from each direction so that they can take turns so as not to interfere with the flow of vehicles from other directions

Display is part of the environment that needs to provide information to a person or user with the aim of making the tasks performed run smoothly. Display in the environment plays a crucial role in providing necessary information to individuals and users, enhancing their ability to perform tasks efficiently and safely. It is important for displays in the environment, such as signage, graphics, and wayfinding systems, to be designed effectively. Signage represents more than directions or policies; it is informational, promotional, and sets the tone of the environment [7]. The meaning of information here concerns all stimuli received by the human senses, either directly or indirectly. One type of display that is often encountered is a visual display. This type of display uses the sense of sight as a recipient of information. The process of designing a display must be given great attention so that the message in it can be conveyed easily and precisely. The display itself is said to be good if it is able to combine sensitivity, accuracy, and speed when delivering the required information.

Visual Cone Angle and Visual Cone Radius: The visual cone angle is a point of view from the human eye to the circle of the target object, while the visual cone radius is the width of visibility received by the human eye or the radius of the circle of visibility received by the human eye.

$$VCA = \frac{180}{\pi} tan^{-1}\left(\frac{\sqrt{(h-1.08)^2 + LATD^2}}{DTSL + LOND + 2.0}\right), (degree)$$

Formula Visual Cone Angel

$$VCR = \frac{Gap}{DTSL + LOND + 2.0}\sqrt{(h-1.08)^2 + \ LATD^2}, (m)$$

Formula Visual Cone Radius

Where:

DTSL : Distance to Stop Line (m), the distance of the vehicle from the stopline

LOND : Longitudinal Displacement, the distance from the traffic light to the stopline

f : the distance between the traffic light pole and the side of the road (m)

h : traffic light height (m),

l : the curved side of the traffic light (m),

gap : the side of the gap between one vehicle and another vehicle,

LATD : latitudinal displacement, or the distance from the driver's focus point to the overhead traffic light.

The driver has a visual angle of approximately 70 degrees that extends as an imaginary cone from their eyes to the front. Meanwhile, according to M. P. R. I. [8] normal human vision when standing is 10 degrees; normal human vision when sitting is 15 degrees; the limit of human vision when seeing colours is 30 degrees; and the limit of human vision is 70 degrees.

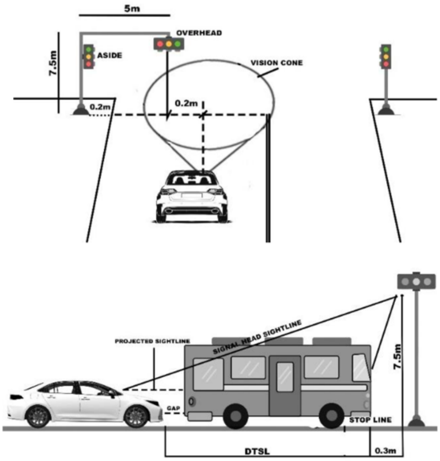
3. RESEARCH METHODS

The type of research used is exploratory research. While the research sites are located at several intersections in the city of Malang. The following are the stages of research carried out to measure, rotate and repair traffic lights in order to reduce accidents by improving the driver's perspective:

- An initial survey regarding complaints and needs for traffic light repairs by users / drivers.
- Measuring the dimensions of the traffic lights at the selected research object.
- Calculate the Visual Cone Angle (VCA) and Visual Cone Radius (VCR) values for existing conditions.
- Compare VCA and VCR values for existing and standard conditions.
- Recommendations for improvements based on analysis of VCA and VCR results, to increase driver awareness and safety.

4. RESULT AND DISCUSSION

The angle of the driver's visual cone when seeing a traffic light will also be different. As for the visuals of a driver while waiting for a traffic light, they are at different heights, and the gap between the driver's vehicle and other drivers is also different. For example, the height of the rider when waiting for the traffic light to turn green is assumed to be 2.1 meters long, 0.7 meters wide, and 1.37 meters high for motorcycles, while for cars it is assumed to be 4.5 meters long, 2.2 meters wide, and 1.5 meters high. And lastly, it is assumed that the length of the vehicle is 7 meters, with a vehicle width of 2.5 meters and a vehicle height of 2.1 meters. As for the gap on motorcycles, it is assumed to be at a distance of 0.5 meters, then the gap for car vehicles is assumed to be at a distance of 1 meter, and finally the gap for trucks is assumed to be at a distance of 1.5 meters. The other existing parameters are used for data processing in the following subsections, such as dtsl, latd, lond, f, h and l based on the formulation 1 and 2. The following is an illustrative image at the Supriadi street intersection as an example of parameters.



Picture 1. Illustration of vehicles at the intersection of S. Supriadi street.

Picture 1 illustrates the traffic light conditions on Supriadi street with the traffic light parameters on Jalan S Supriadi being h = 0.2 meters, l = 5 meters, f = 0.2 meters, LONG = 0.3 meters, and LATD = 0.2 meters. The results of measuring the parameter data above and several roads other than Supriadi street can be seen in the following table 1:

Table 1. Vision Cone Parameter Data for Existing Conditions

No	Street Name	LATD (m)	LOND (m)	f (m)	h (m)	l m)
1	S Supriadi	0.2	0.3	0.2	7.5	5
2	Janti Barat	0	0.35	1.2	6	0
3	Kawi (Ijen)	1.05	0	1.2	6	5.5
4	Ry Sby – Mlg	2.65	0	0.5	10	6.5
5	MT.Haryono	0.6	0	0.5	8.5	5
6	Jalan Arjuno	0	1.1	0.5	5	0
7	Borobudur	0	0	0.2	6	0
8	Besar Ijen	0	2.5	0.5	4.5	0
9	Arif Margono	0.2	0.7	0.4	7	6
10	I.R. Rais	0	0	1.2	6	0

Based on the results of the vision cone parameter data above, vision cone angle (VCA) data processing is carried out on one of the roads, namely Supriadi street by using the formula:

$$VCA = \frac{180}{\pi} tan^{-1}\left(\frac{\sqrt{(h-1.08)^2 + LATD^2}}{DTSL + LOND + 2.0}\right), (degree)$$

VCA on motorcycle:

$$VCA = \frac{180}{\pi} tan^{-1}\left(\frac{\sqrt{(h - 1.08)^2 + LATD^2}}{DTSL + LOND + 2.0}\right)$$

$$VCA = \frac{180}{\pi} tan^{-1}\left(\frac{\sqrt{(7.5 - 1.08)^2 + 0.2^2}}{2.1 + 0.5 + 0.3 + 2.0}\right)$$

$$VCA = 52^o$$

Based on the calculation of the vision cone angle data processing with the existing conditions on the Supriadi road using the parameters of motorbikes, cars, and trucks, it is known that drivers with truck vehicles are more focused on their explanation with a vision cone angle of 30 degrees, while drivers using cars see traffic lights with a vision cone angle of 39 degrees, and finally, drivers using motorbikes focus their vision on traffic lights, almost reaching the maximum limit. The driver sees the traffic light with a vision cone angle of 52 degrees. The results of vision cone angle (VCA) data processing based on existing conditions at each intersection can be seen in the following table.

Table 2. Vision Cone Angle (VCA) Results with Existing Conditions

No	**Street Name**	***Vision Cone Angle* (VCA)**		
		Motorcycle	**Car**	**Truck**
1	S.Supriadi	52°	39 °	30 °
2	Janti Barat	44 °	32 °	24 °
3	Kawi (Ijen)	47 °	33 °	25 °
4	Raya Surabaya – Malang	63 °	51 °	41 °
5	MT. Haryono	58 °	44 °	35 °
6	Arjuno	34 °	24 °	18 °
7	Borobudur	46 °	33 °	25 °
8	Besar Ijen	25 °	18 °	14 °
9	Arif Margono	48 °	35 °	27 °
10	I.R. Rais	46 °	33 °	25 °

Based on Table 2, it is known that the highest vision cone angle on motorcycles is at an angle of 63 degrees, and the lowest vision cone angle on motorcycles is at an angle of 25 degrees. Meanwhile, the highest vision cone angle on a car is at an angle of 51 degrees, with the lowest vision cone angle on a car being at an angle of 18 degrees. And the highest vision cone angle on a truck is at an angle of 41 degrees, with the lowest vision cone angle on a truck being at an angle of 14 degrees.

From the previous explanation, it can be explained that the average vision cone angle (VCA) on motorbikes is 47 degrees or below the parameter of 60 degrees, which means it can still be seen by the driver's vision, but even though the vision cone angle (VCA) on motorbikes is below the driver's visibility parameters when looking at a traffic light, the focus limit when driving is only 15 degrees if calculated from one side only, while for two sides the focus limit is 30 degrees, so improvements should be made based on standard parameter data to reduce the driver's vision angle. Motorcycle with the aim of allowing car drivers to ride comfortably and be more focused when waiting for the green light at traffic light intersections.

And the average vision cone angle (VCA) on a car vehicle is 35 degrees or below the parameter of 60 degrees, which means it can still be seen by the driver's vision, but even though the vision cone angle (VCA) on a car vehicle is below the driver's visibility parameter when looking at a traffic light, the focus limit for driving is only 15 degrees if calculated from one side only, while for two sides the focus limit is 30 degrees, so improvements should be made based on standard parameter data with the aim of reducing the vision cone angle (VCA) of car drivers so that motorists can drive comfortably and be more focused while waiting for the green light at a traffic light intersection.

Meanwhile, the average vision cone angle (VCA) in truck vehicles is 27 degrees or below the parameter of 60 degrees, which means it can still be seen by the driver's vision, and the vision cone angle (VCA) in truck drivers is below the focus limit parameter when driving, namely below 30 degrees. So it is known that even if repairs are not carried out on trucks, truck drivers can drive comfortably and be more focused when waiting for the green light at traffic light intersections. The following is the processing of vision cone angle (VCA) data based on traffic light dimensions and other standards.

Table 3. Vision Cone Angle (VCA) Results with Standard Parameters

No	**Street name**	***Vision Cone Angle* (VCA)**

		Motorcyle	Car	Truck
1	S.Supriadi	38°	29 °	23 °
2	Janti Barat	38 °	29 °	23 °
3	Kawi (Ijen)	45 °	35 °	28 °
4	Raya Surabaya – Malang	44 °	34 °	27 °
5	MT. Haryono	40 °	30 °	24 °
6	Arjuno	35 °	26 °	22 °
7	Borobudur	40 °	30 °	24 °
8	Besar Ijen	29 °	23 °	19 °
9	Arif Margono	36 °	28 °	23 °
10	I.R. Rais	40 °	30 °	24 °

Based on Table 3, it is known that the highest vision cone angle on motorcycles is at an angle of 45 degrees, and the lowest vision cone angle on motorcycles is at an angle of 29 degrees. Meanwhile, the highest vision cone angle for cars is at an angle of 35 degrees, while the lowest vision cone angle for cars is at an angle of 23 degrees. And the highest vision cone angle on trucks is at an angle of 28 degrees, while the lowest vision cone angle on trucks is at an angle of 19 degrees.

Here it can be explained that the vision cone angle (VCA) on an average motorcycle is 38 degrees or below the 60 degree parameter, which means it can still be seen by the driver's vision, and the vision cone angle (VCA) on a motorcycle is still above the limit parameter. The focus when driving is 30 degrees. So it is known that the vision cone angle on motorbike riders using standard parameters is better than the vision cone angle on motorbikes using existing conditions, and it can be explained that the visibility of motorbike riders while waiting for the green light on the traffic light is still visible but not within the focus range. Motorists are still not clearly seeing traffic lights.

And it is also explained in Table 5 that the average vision cone angle (VCA) for car vehicles is 29 degrees or below the 60 degree parameter, which means it can still be seen by the driver's vision, and the vision cone angle (VCA) for car drivers is below the limit parameter. Focus when driving is below 30 degrees. So it is known that the vision cone angle of car drivers using standard parameters is better than the vision cone angle of car drivers based on existing conditions, and it can be explained that even though no repairs have been made to car drivers, car drivers can drive comfortably and be more focused when waiting for the lights. Green at a traffic light intersection.

Meanwhile, the average vision cone angle (VCA) in truck vehicles is 23 degrees, or below the parameter of 60 degrees, which means it can still be seen by the driver's vision, and the vision cone angle (VCA) in truck drivers is below the focus limit parameter when driving, namely below 30 degrees. So it is known that the vision cone angle (VCA) for truck drivers using standard parameters is better, namely 23 degrees, than the vision cone angle for truck drivers based on existing conditions, namely 27 degrees, and this can be explained if, in the position of the truck driver, even though no repairs have been made, the vehicle driver can drive comfortably and is more focused when waiting for the green light at traffic light intersections than the other two types of vehicles.

After getting the vision cone angle (VCA), the next step is to process the vision cone radius (VCR) data on one of them, namely Supriadi street by using the formula:

$$VCR = \frac{Gap}{DTSL + LOND + 2.0}\sqrt{(h - 1.08)^2 + LATD^2}$$

VCR on motorcycle:

$$VCR = \frac{0.5}{2.1 + 0.5 + 0.3 + 2.0}\sqrt{(7.5 - 1.08)^2 + 0.2^2}$$
$$VCR = 0.65\ Meter$$

Based on data processing calculations of the vision cone radius with existing conditions on Supriadi street using motorbike, car, and truck vehicle parameters, it is known that drivers with cars and trucks can still see traffic lights comfortably because the vision cone radius is below the gap of each vehicle. Namely, a car gap of 1 meter and a truck gap of 1.5 meters, so that car and truck drivers can still see the traffic lights clearly. In contrast to the two previous vehicles, motorcycle drivers still have difficulty seeing traffic lights. The reason is that the driver's visibility circle does not reach the traffic light. This is explained by the vision cone radius of motorbike drivers, which is greater than the motorbike gap, namely 0.65 meters, while the motorbike exiting gap is 0.5 meters. The results of vision cone radius (VCR) data processing based on existing conditions at each intersection can be seen in Table 4.

Table 4. Results of Vision Cone Radius (VCR) with Existing Conditions

No	Street name	*Vision Cone Radius* (VCR)		
		Motorcycle	Car	Truck
1	S.Supriadi	0,65	0,82	0,89
2	Janti Barat	0,49	0,62	0,68
3	Kawi (Ijen)	0,54	0,67	0,71
4	Raya Surabaya – Malang	1,02	1,25	1,34
5	MT. Haryono	0,80	0,99	1,06
6	Arjuno	0,34	0,45	0,50
7	Borobudur	0,53	0,65	0,70
8	Besar Ijen	0,24	0,34	0,39
9	Arif Margono	0,55	0,72	0,79
10	I.R. Rais	0,53	0,65	0,70

Based on table 4, it is known that the highest vision cone radius (VCR) for motorbikes is 1.02 meters and the lowest vision cone radius (VCR) for motorcycles is 0.24 meters. Meanwhile, the highest vision cone radius (VCR) in cars is 1.25 meters and the lowest vision cone radius (VCR) in cars is 0.34 meters. And the highest vision cone radius (VCR) on trucks is 1.34 meters and the lowest vision cone radius (VCR) on trucks is 0.39 meters.

It can be explained that the vision cone radius (VCR) on motorcycles is 0.57 meters or above the vision cone radius parameter, which means that motorcycle drivers still have difficulty seeing traffic lights. The reason is that the driver's visibility circle does not reach the traffic light. This is explained by the vision cone radius of a motorbike driver, which is greater than the motorbike gap, namely 0.57 meters, which is rounded up to 0.6 meters, while the motorbike exiting gap is 0.5 meters. So improvements should be made based on standard parameter data, with the aim of making motorcycle drivers able to see traffic lights comfortably.

Then it was also explained that the vision cone radius (VCR) in car vehicles is 0.72 meters or below the vision cone radius parameter, which means that car drivers can easily see traffic lights or that the visibility circle for car drivers can reach traffic lights. This is explained by the vision cone radius of the car driver being less than the car gap, namely 0.72 meters, while the car exiting gap is 1 meter. Whether improvements are made based on standard parameter data or not, car drivers can still reach traffic lights comfortably.

It was explained that the vision cone radius (VCR) on truck vehicles is 0.78 meters or below the vision cone radius parameter, which means that truck drivers can easily see the traffic light or the visibility circle for truck drivers can reach the traffic light. This is explained by the truck driver's vision cone radius being less than the car's gap, namely 0.78 meters, while the car's existing gap is 1.5 meters. Whether improvements are made based on standard parameter data or not, car drivers can still reach traffic lights comfortably. The following is the processing of vision cone radius (VCR) data based on traffic light dimensions and other standards.

Table 5. Vision Cone Radius (VCR) Results with Standard Parameters

No	Street name	*Vision Cone Radius* (VCR)		
		Motorcycle	Car	Truck
1	S.Supriadi	0,8	0,56	0,44
2	Janti Barat	0,79	0,55	0,43
3	Kawi (Ijen)	1	0,7	0,55
4	Raya Surabaya – Malang	0,99	0,67	0,53
5	MT. Haryono	0,85	0,58	0,45
6	Arjuno	0,7	0,5	0,4
7	Borobudur	0,57	0,43	0,36
8	Besar Ijen	0,57	0,43	0,36
9	Arif Margono	0,74	0,53	0,42
10	I.R. Rais	0,85	0,58	0,45

Based on Table 5, it is known that the highest vision cone radius (VCR) on motorcycles is 1 meter and the lowest vision cone radius (VCR) on motorcycles is 0.57 meters. Meanwhile, the highest vision cone radius (VCR) for cars is

0.7 meters, and the lowest vision cone radius (VCR) for cars is 0.43 meters. And the highest vision cone radius (VCR) for trucks is 0.55 meters, and the lowest vision cone radius (VCR) for trucks is 0.36 meters.

From the previous explanation, it can be explained that the vision cone radius (VCR) on motorcycles is 0.82 meters or below the vision cone radius parameter, which means that motorbike riders can easily see traffic lights or the visibility circle of car drivers can reach traffic lights. This is explained by the vision cone radius of motorcycle riders, which is less than the gap of a motorcycle, which is 0.82 meters, while the standard parameter for a car gap is 1 meter. So it can also be explained that the vision cone radius based on standard parameters is better than the existing conditions, even though in the existing conditions the vision cone radius is lower than the vision cone radius based on standard parameters. This is because the vision cone radius based on existing conditions is 0.57, or if it is rounded up, it is 0.6 meters more than the gap in existing motorcycle conditions, which is 0.5. Meanwhile, for the vision cone, the radius based on the standard parameter conditions is 0.82 meters and does not exceed the standard gap parameter, namely 1 meter.

Then it was also explained that the vision cone radius (VCR) in car vehicles is 0.57 meters or below the vision cone radius parameter, which means car drivers can easily see traffic lights or the visibility circle of car drivers can reach traffic lights. This is explained by the vision cone radius of car drivers, which is less than the gap of a car, which is 0.57 meters, while the standard parameter for a car gap is 1 meter. So it can also be explained that the vision cone radius based on standard parameters is better than the existing conditions, where the vision cone radius for car drivers based on parameters is 0.57 meters and the vision cone radius for car drivers is 0.72 meters.

Finally, it was explained that the vision cone radius (VCR) on truck vehicles is 0.44 meters or below the vision cone radius parameter, which means that truck drivers can easily see the traffic light or the visibility circle for truck drivers can reach the traffic light. This is explained by the fact that the vision cone radius of a truck driver is less than the car gap, namely 0.44 meters, while the standard parameter for a car gap is 1 meter. So it can also be explained that the vision cone radius based on standard parameters is better than the existing conditions, where the vision cone radius for truck drivers based on parameters is 0.44 meters and the vision cone radius for car drivers is 0.78 meters.

Improving traffic light dimensions is one method used to reduce high levels of vision cone angle and vision cone radius. The reason traffic accidents occur is that the dimensions of the traffic light are too high so that the driver's visibility cannot reach the traffic light object. Therefore, the proposed standard parameters for traffic light dimensions should be at a height of 5.5 meters so that drivers can see the traffic light comfortably.

Improvements to the distance between the stop line and the traffic light, or what is usually called Longitudinal Displacement (LOND) are carried out to determine the distance between drivers who are waiting for the green light at the traffic light based on standard conditions. Longitudinal displacement (LOND) settings should be done at a distance of at least 1 meter. Meanwhile, in existing conditions, the distance between the stop line and the traffic light tends to be below the traffic light, which makes drivers uncomfortable when waiting for the green light at the traffic light.

5. CONCLUSION

1. The results obtained based on standard parameters are better than the results in existing conditions, this is due to the dimensions of the traffic light and the dimensions of each vehicle.
2. In addressing the dimensions of the traffic light and gaps for each different vehicle, a recommendation is given in the form of changing the dimensions of the traffic light to match the standard parameters because by changing the dimensions of the traffic light and gap, the visibility of the driver when waiting for the green light at the intersection can reach the object traffic.
3. The reason for recommending improvements to the longitudinal displacement is that, based on the existing conditions, the longitudinal displacement distance tends to be in line with the traffic light. So improvements need to be made based on standard parameters so that drivers in the front vehicle can achieve visibility at the traffic light object.

AUTHORS' CONTRIBUTIONS

Sugiono developed conceptualisation and research methodology, Rio Prasetyo Lukodono and Nur Muhammad Fathurrahman collected the data, Wisnu Wijayanto and Bambang Indrayadi analysed the data, Rahma Sabilah Nurbi and Hari Sudjono edited the article.

ACKNOWLEDGMENTS

Our acknowledgement goes to the ministry of national education of the republic of indonesia for supporting this study. The researchers would also like to express their gratitude to the Brawijaya University, Malang, Indonesia, for their extraordinary encouragement. The study was performed with the financial support by Badan Penelitian & Pengabdian Masyarakat (BPPM), Engineering Faculty, Universitas Brawijaya through Dipa Grant 2023 Program.

REFERENCES

[1] Liu, Y., Li, Z., Liu, J., & Patel, H. (2016, September 1). Vehicular crash data used to rank intersections by injury crash frequency and severity. Data in Brief, 8, 930-933. https://doi.org/10.1016/j.dib.2016.06.046.

[2] Gligorović, B., Desnica, E., & Palinkaš, I. (2018, August 10). The importance of ergonomics in schools – secondary technical school students' opinion on the comfort of furniture in the classroom for computer aided design. https://doi.org/10.1088/1757-899x/393/1/012111.

[3] Dul, J., Vries, H D., Verschoof, S., Eveleens, W., & Feilzer, A J. (2004, November 1). Combining economic and social goals in the design of production systems by using ergonomics standards. https://doi.org/10.1016/j.cie.2004.07.005.

[4] Imran, M S., & Ewadh, H A. (2020, January 1). Control and traffic signal warrant assessment of intersection sites. https://doi.org/10.1088/1757-899x/671/1/012057.

[5] Güneş, F., Bayrakli, S., & Zaim, A H. (2021, July 24). Smart Cities and Data Analytics for Intelligent Transportation Systems: An Analytical Model for Scheduling Phases and Traffic Lights at Signalized Intersections. https://doi.org/10.3390/app11156816.

[6] Stempler, A F., & Polger, M A. (2014, November 9). Do You See the Signs?. https://www.tandfonline.com/doi/abs/10.1080/15228959.2013.785881.

[7] Mujahidin, Mujahidin. (2010). Perancangan Display Visual Kuantitatif Pada Sistem Manusia Mesin. Jurnal Teknik Industri. 1. 31. 10.22219/JTIUMM.Vol1.No1.31-39.

[8] M. P. R. I., "Peraturan Menteri Perhubungan Republik Indonesia Nomor PM 49 Tahun 2014," in *Alat Pemberi Isyarat Lalu Lintas (APILL)*, Menteri Perhubungan Republik Indonesia, 2014.