Sustainable road-kill mitigation in Gladak Perak Bridge at Lumajang, Indonesia

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Sustainable road-kill mitigation in Gladak Perak Bridge at Lumajang, Indonesia

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Abstract. Traffic accidents involving animals occur every year. Roadkill is a serious problem faced by the whole world, including Indonesia. Therefore, it is necessary to modify road accessories to prevent accidents, both from animals and road users. Prevention can be done in several ways, such as by installing fences or creating crossing paths, for animals. The fence can be used as a barrier between the driving lane and the animal path, where they can carry out activities such as playing without disturbing road users. Meanwhile, the making of crossing paths can be used by animals as access for animal migration. This study would like to propose a design for implementing cross-fencing mitigation at Gladak Perak Bridge at Lumajang, Indonesia. This location is an accident-prone area due to the sudden crossing of monkeys, which has been a myth in the community. Through the implementation of the installation of road dividers, it is hoped that the road design at the research site becomes wildlife friendly road and the management of traffic also meet the Indonesian design standards for inter-city roads without reducing tourism potential.

1. Introduction

Traffic accidents kill hundreds of millions of animals each year. These accidents are a threat to many animal species, as shown in Figure 1 [1]. Figure 1 shows that mammals were the highest accident victims in the study. The number of accidents found was 72 out of 45 scientific studies of literature. The y-axis on the white bars represent the number of literature, and the green bars represent the estimated frequency of accidents in the 1981-2015 time range. This mammal also includes monkeys, who are the object of this study. More than 40 types of road accident mitigation are calculated to reduce the mortality of wild animals.

In Indonesia, monkeys are primates that are often being victims. On February 23, 2021, there was an accident where the police crashed the monkey [2]. Not long after, the fallen policeman was attacked by another herd of monkeys, who wanted to protect their friend's corpse. This incident is located at the Gladak Perak Bridge, Lumajang Regency. The route is often used by herds of monkeys as a playing location. It is very possible since Gladak Perak is a nature reserve and cultural heritage.

Monkey accidents did not just happen this time. On January 27, 2021, 2 female riders in Bukit Baling Village, Muaro Jambi Regency had to be taken to the hospital after hitting a monkey crossing the road [3]. In fact, on July 12, 2018, 2 motorcyclists were killed by a truck in Tanjung Payang Village, Lahat Regency [4]. The victim's head was crushed by the rear tire of the truck after hitting the monkey, who suddenly crossed and fell.

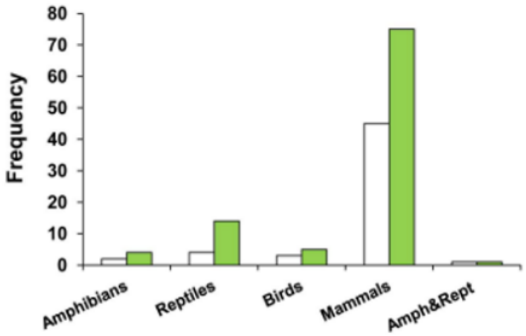

Figure 1. Number of Accidents by Taxon [1].

In fact, because of the frequent accidents caused by monkeys, in Tanjakan Si Emen, Subang Regency there is a myth that if a group of monkeys crosses it means that there will be an accident [5]. It is associated with mystical things such as having to give cigarettes and coffee to refuse bad luck. The same thing also happened at this study location, the Gladak Perak Bridge, or better known as the Piket Nol Bridge [6]. This location is considered haunted because it was the location for the disposal of the bodies of the G30S PKI tragedy in Indonesia history [7]. A single accident that occurs is often associated with spirits in the human form of monkeys suddenly crossing over. Conditions with minimal lighting and sharp bends at both ends of the bridge exacerbated the accident [8]. The spirit in the form of a human is likely a monkey who is crossing. With this research, it is hoped that the local community can obtain scientific solutions to overcome the myth of traffic accidents there.

In addition, the Gladak Perak Bridge or better known as Piket Nol is also a popular historical tourist destination, so it can attract visitors [9]. Unfortunately, most visitors choose to stop at the edge of the main road that is actively used, thereby endangering other road users as shown in Figure 2 [10]. Rte 3 Street is a 2-lane and 2-direction highway, so there is no space to stop. By referring to the law of probability, the more the number of visitors, the higher the number of accidents. This accident also includes interactions with monkeys at the study site. Therefore, with the implementation of the results of this study, it is hoped that animals will no longer enter the highway, there will be improvements in traffic arrangements related to stops, and improvements in the arrangement of tourist sites in related locations. In addition, this research is expected to spur awareness on the topic of road-kill animals, especially in Indonesia.

Figure 2. Number of Accidents by Taxon [10].

2. Literature review

2.1. Lumajang Regency development

Lumajang is a regency located in East Java Province, Indonesia (Figure 3). This regency has several tourist destinations that are quite interesting to visit. Even so, Lumajang has a fairly diverse and untouched regional character. According to existing data, around 114,238.05 Ha or about 63.79% of Lumajang Regency is forest, both production forest and community forest [11]. Not only that, the population of wild animals in Lumajang is quite large. A lot of news reports about the attack of wild animals into residential areas and onto roads, especially monkeys. This can lead to traffic accidents that can harm residents and threaten the monkey population. Therefore, the government needs to exercise control to keep the monkey population of Lumajang Regency sustained and does not cause traffic accidents. Land use of Lumajang Regency can be seen in Table 1.

Figure 3. Lumajang Residence Map [11].

Table 1. Land Use of Lumajang Regency [11].

Land Use	Area (Ha)
Protected Forest Area	11527.60
National Parks	23539.45
Production Forest Area	22735.00
Community Forest Area	56436.00
Total Forest Area	**114238.05**
Other Uses :	**64851.95**
Residental Area	15927.00
Argicultural Area	35993.00
Plantation Area	9921.00
Fishing (Fishpond)	127.00
River	2883.95

2.2. Urbanization

Urbanization is the movement of people from outside the city/village to the city [12]. Urbanization can occur due to high population growth. This can lead to physical expansion both in urban areas and in the area of roads used. If urbanization continues, the residential area will become wider while the environmental area will be eroded. Not only can lead to the endangerment of wild plant and animal populations, and even extinction, but also wild animals can also appear in residential areas due to a lack of food supply. Therefore, a solution is needed to keep the human population and other living things awake even though it continues to experience population growth.

2.3. Environment

Human life cannot be separated from the environment. The environment provides everything that humans need, such as clean air, clean water, food, and clothing. Even so, most humans are unable to manage the environment in which they live. Humans only want to take advantage and utilize the resources generated by the environment without taking care of them. As a result, the environment, which should have been the source of human life, has become a disaster for humans. Wild animals also attack residential areas because their homes are threatened and deprived of food. Therefore, it is necessary to control so that humans and nature can coexist.

The environment cannot be separated from the living things in it. In designing a road, it is necessary to understand the behavior of living things, especially animals (Figure 4). Roads that cut through forest paths or areas where animals live can lead to accidents caused by wild animals (Figure 5). This can happen because their habitat is eroded, so they migrate through the highway [13]. This animal migration is done so that they can survive, such as foraging for food, looking for new places to live, and looking for places to breed. In addition, the reason wild animals can be on the road could also be because they do not know that the road is dangerous when they are playing [14]. Therefore, it is necessary to rethink how to separate animals from the road.

Figure 4. The highway as a place to play a herd of monkeys [15].

Figure 5. Monkey Roadkill [16].

2.4. Accident mitigation

Mitigation is a series of efforts to minimize the occurrence of disasters. These disasters can be caused by natural, non-natural, and human causes. Mitigation efforts can be carried out in 2 ways, namely through physical buildings and through public awareness [16]. Through mitigation, it is hoped that it can reduce the risk of detrimental things, both in the form of property loss, natural damage, psychological disorders, to the appearance of casualties.

About mitigation, roads are areas prone to accidents that cause casualties. Accidents can arise from several factors, namely road design, human factors, and natural factors, especially animals [17]. According to research, hundreds of millions of animals die each year due to traffic accidents [18]. Animals can enter the road area because they do not know about the dangers that exist. Even so, the Indonesian government has not yet mitigated these dangers. Therefore, mitigation is needed to reduce the number of fatalities due to traffic accidents caused by animals.

According to research, mitigation can reduce the number of traffic accidents caused by animals by 40%, higher than road control. Meanwhile, mitigation in the form of fences and crossings can reduce animal roadkill by 54%. In addition, combining fences with crossing structures, as shown in Figure 6, can reduce the number of accidents caused by animals by 83% [19]. This is certainly suitable if applied in Indonesia, considering that Indonesia is a country with the second-largest biodiversity in the world.

Figure 6. Wildlife crossing structure [20].

2.5. Crossing-fencing

Crossing-fencing is a fence that is installed lengthwise to become a barrier between one place and another (Figure 7). Crossing-fencing was created as a form of mitigation aimed at reducing the number of traffic accidents caused by wild animals [21]. According to research, crossing-fencing is the most effective way to prevent wild animals from entering the resident area. In addition, crossing-fencing is the method most often used to limit the movement of wild animals because of its easy installation, low cost, and durability [22].

Figure 7. Wildlife crossing-fencing [23].

3. Research methodology

3.1. Research Location

Figure 8. Street View [24].

Figure 9. Satellite View [24].

This study is located at the new Gladak Perak Bridge, precisely in Lumajang Regency. This bridge is alternative access to Malang-Lumajang (Figure 8), which is often being used as the play zone and migration of monkeys around the bridge. The location of the bridge which is surrounded by forests and tall trees supports the monkeys to make it a favorite place (Figure 9). The research focus is to design the accessories of National Rte 3 Street so that it can be friendlier to endemic fauna and provide a sense of security for road users so that they can avoid traffic accidents.

The New Gladak Perak Bridge was built in 2001 by the Indonesian government as a replacement for the old bridge from the Dutch colonial era (1925-1940). This new bridge has dimensions of 130 m long and approximately 6 m wide [25]. Meanwhile, on the opposite, there is an old bridge that has a length of 100 m and a width of 3 m [9]. The location of the old and new bridges are in adjacent locations with a height of approximately 750 masl as shown in Figure 10 [26]. For this research, the author redesigned the new Gladak Perak Bridge.

Figure 10. The Old and New Gladak Perak Bridge Location [26].

3.2. Data Collection Method

The author's data collection method uses software that contains a map of the location and local conditions, including:

1. Google Earth Pro to determine contour and existing points around
2. ArcGIS to complement the situation around the research site

The collected data will be the main consideration in road mitigation redesign and will be supported by previous literature studies.

3.3. Road Mitigation Design Method

In redesigning the road mitigation, the writer uses AutoCAD software to do a rough drawing, then applies it in 3D with SketchUp to produce the final design. For design standards, the author uses Tata Cara Perencanaan Geometrik Jalan Antar Kota (TPGJAK) 038/TBM/1997 and Keputusan Direktorat Jenderal Perhubungan Darat No. SK. 43/AJ 007/DRJD/97. The aspects that the writer uses include the width of the road, the width of the sidewalk, the height of the structure based on the height of the permitted type of vehicle, and the classification of the road.

The road class of Gladak Perak Bridge is an intercity road with a collector function. The road is an undivided 2-lane-2-way, equipped with sidewalks. Collector Road definition based on TPGJAK 1997 [27] is a road that serves collector/distributor transportation with the characteristics of medium distance travel, moderate average speed, and a limited number of entrances. Arterial and collector-type roads should not be disturbed by local activities, including vehicles that stop on the side of the road. Based on this characteristic, the author provides a no-stop sign to control local activities.

From Table 2, the ideal lane width of the collector road is 3 m [27]. The recommended sidewalk width for collector roads is 1 m (Table 3) with maximum height of 25 cm [28]. Table 4 shows that the minimum height of the structure is 4.1 m [27]. These data will be used as the basic reference in the design of crossing-fencing mitigation.

Table 2. Ideal Lane Width by Road Function and Classification [27].

Function	Class	Area (Ha)
Arterial	I	3.75
	II, IIIA	3.50
Collector	IIIA, IIIB	3.00
Local	IIIC	3.00

Table 3. Sidewalk Width by Surrounding Land Use [28].

Surrounding Land Use	Minimum Sidewalk Width (m)	Recommended Sidewalk Width (m)
Residential	1.5	2.75
Office	2	3
Industrial	2	3
School	2	3
Bus Stop/Terminal	2	3
Shopping District	2	4
Bridge/Tunnel	1	1

Table 4. Design Vehicle Specifications as Traffic Load [27].

Design Vehicle Category	Vehicle Dimension (cm)			Bulge (cm)		Turning Radius		Buldge Radius (cm)
	Height	Width	Length	Front	Rear	Minimum	Maximum	
Small Vehicle	130	210	580	90	150	420	730	780
Medium Vehicle	410	280	1210	210	240	740	1280	1410
Large Vehicle	410	260	2100	120	90	290	1400	1370

4. Data and analysis

The mitigation method that the author uses is crossing-fencing. The design model of crossing-fencing are shown in Figures 11 to Figure 18. These figures show the result of the redesign that the author has made as a solution to the road-kill problems on the Gladak Perak Bridge.

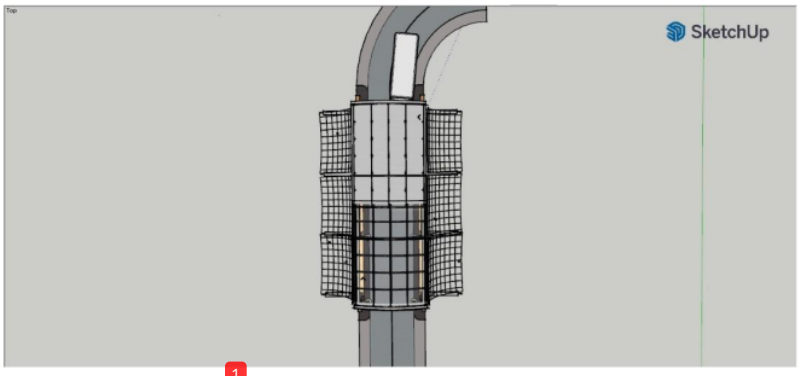

Figure 11. Top View (Transversal).

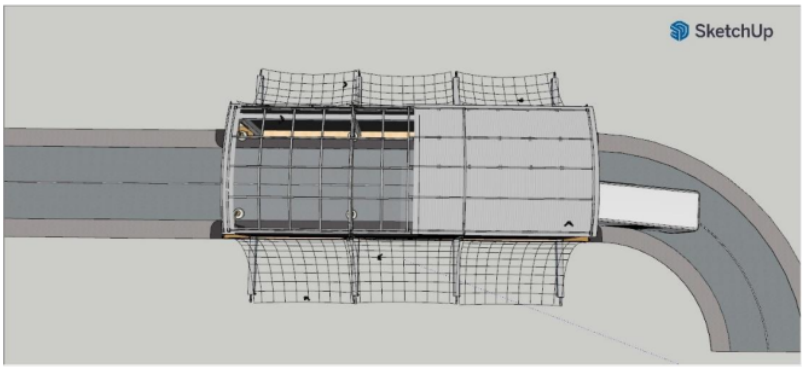

Figure 12. Top View (Longitudinal).

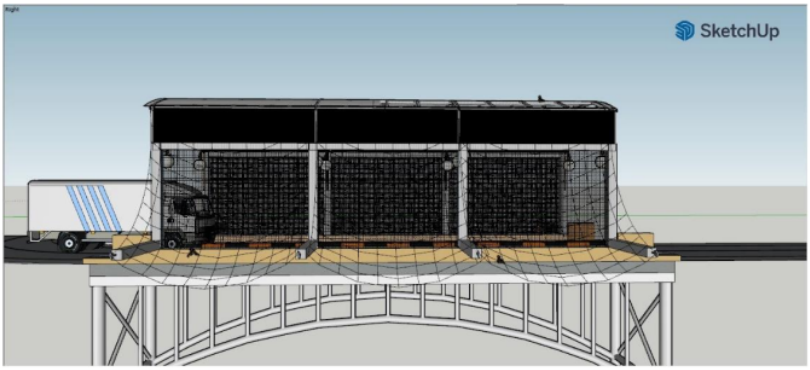

Figure 13. Right View.

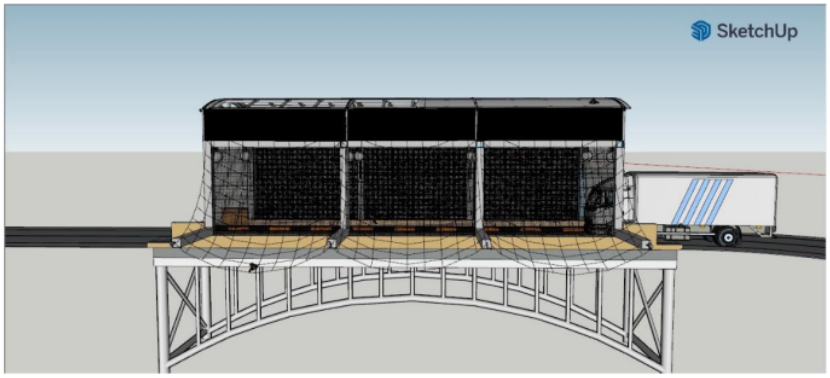

Figure 14. Left View.

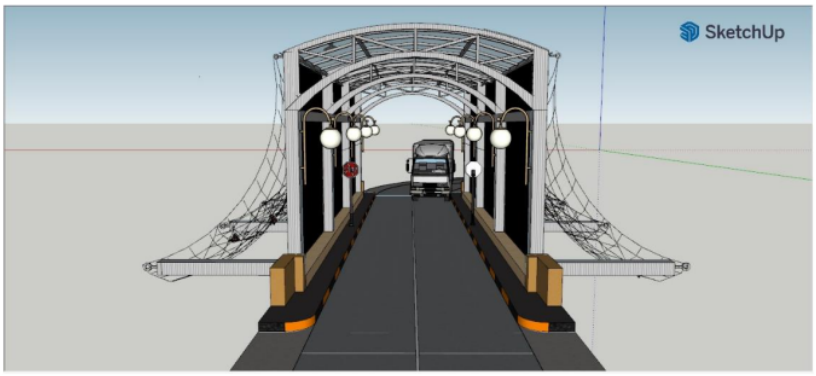

Figure 15. Front View.

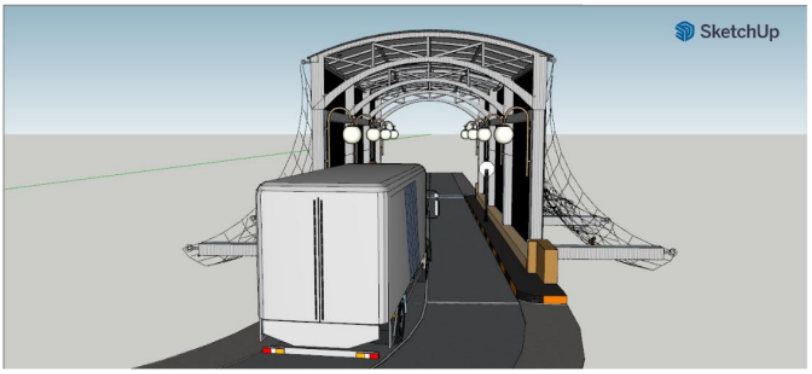

Figure 16. Back View.

Figure 17. Inside View.

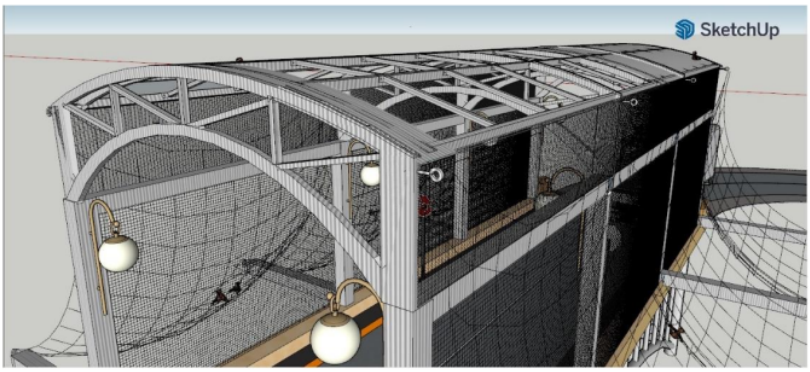

Figure 18. 3D View.

4.1. Design Specification

The design uses the following specifications:

1. The supporting column uses reinforced concrete with dimensions of 300 x 300 mm, with a distance between columns of 6 m and a height of 3.75 m from the upper surface of the bottom longitudinal beam. The total height of the structure from the upper surface of the asphalt to the upper surface of the top longitudinal beam is 4.25 m which meets TPGJAK 1997 standard (Figure 19).
2. The streetlamps used are 10 Watt Luxon Public Street Lighting LEDs which are installed every 6 m (Figure 19).
3. The sidewalk area is 1 m in width and 0.2 m in height along the road as stated in Keputusan Direktorat Jenderal Perhubungan Darat No. SK. 43/AJ 007/DRJD/97 standard with a traffic sign "no stopping" considering the road is 2 lanes-2 directions with a limited road width (Figure 19).
4. The steel wire surrounds the side of the bridge and covers the sides of the roof using Stainless Steel Wire Rope Mesh with a cavity width of 5 cm to prevent monkeys from entering the road (Figure 19).
5. Traffic signs "no stopping" are installed to meet the prerequisites that the traffic flow of the Collector Road must not be disturbed by local activities. (Figure 19)

Figure 19. Supporting Column with Sidewalk Accessories.

6. The top and the bottom of the longitudinal beam uses reinforced concrete with dimensions of 200 x 300 mm with a length of 6 m (Figure 20).

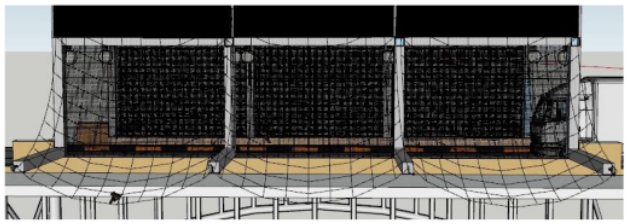

Figure 20. 6 m Supporting Longitudinal Beam.

7. 1 m long cantilevered transverse beam using reinforced concrete on the lower side with dimensions of 150 x 300 mm (Figure 21).

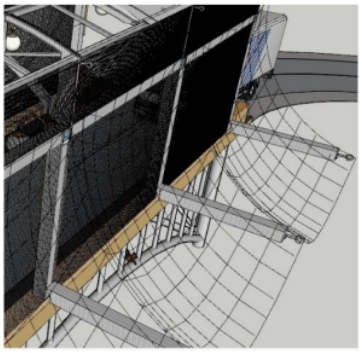

Figure 21. 1 m Cantilevered Transverse Beam.

8. The nets on the edge of the bridge for monkeys are made of nylon with a thickness of 16 mm and a hole of 20 x 20 cm. The dimensions of the hole are adjusted to the height of the Lumajang monkey, which ranges from 20-30 cm and has a width of approximately 10 cm. With large holes, those monkeys can mobilize easily and will not be trapped. The ropes will be attached to the lower cantilevered crossbeams and upper hooks every 6 m (Figure 22).

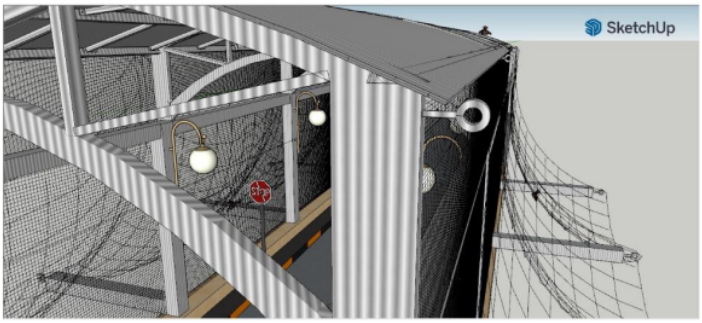

Figure 22. Hook and Cantilevered Beam Attachment for Nylon Nets.

9. The short column roof uses reinforced concrete with dimensions of 250 x 250 mm along 0.5 m and is provided with a connection for the attachment of the roof frame (Figure 23).

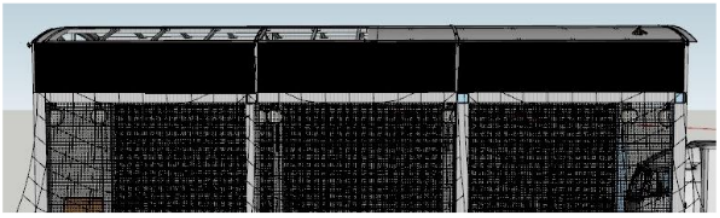

Figure 23. Short Column Roof.

10. The roof frame uses a lightweight steel truss with a span of 8 m which adapts the existing width of the road (Figure 24).

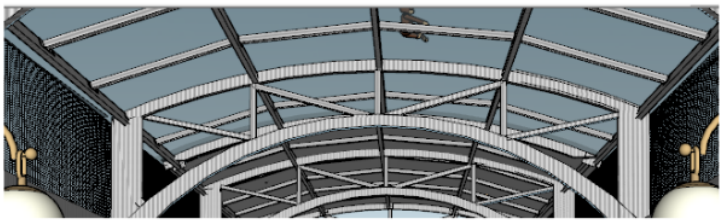

Figure 24. Lightweight Steel Truss for Roof Frame.

11. The curved roof covering uses curved spandex with a composition of 43% zinc, 55% aluminum, and 1.5% silicon (Figure 25).

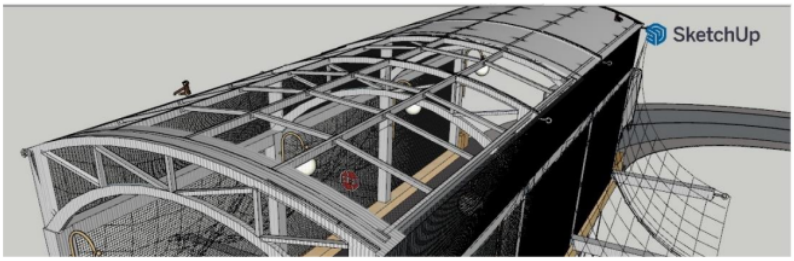

Figure 25. Curved Spandex Roof.

4.2. Road accessories analysis

The analysis of the new accessories road design in this study are as following descriptions:

1. The roof is curved to give the aesthetic side of the design and make it easier for the monkeys to cross over the side of the bridge roof.
2. Nylon nets that are placed on each side of the bridge are used for the monkey's playing and relaxing locations, considering that existing data indicate that this location is indeed a play area for the monkeys so that they do not lose their place. In addition, pedestrians can also make this location a spot to interact with monkeys.
3. Steel wire walls are provided to prevent endemic monkeys from suddenly crossing or entering road areas so that the number of accidents caused by wild animals can be reduced.
4. Steel wire on the roof is provided to make it easier for the monkeys to grip when climbing and crossing, given the spandex material tends to have a smooth surface.

5. The bridge is designed to have the lowest height of 4.25 m so that it allows large vehicles such as trucks and buses to keep crossing the alternative roads.
6. Illumination is given every 6 m on both sides of the road, considering the existing data shows the research location is still lacking lighting, causing a single accident and, is often associated with mystical things. With sufficient street lighting, it is hoped that the number of accidents can be reduced. In addition, at night, the lighting will add to the aesthetic value of the bridge.

4.3. Problems without road mitigation design

Problems that will arise if the road accessories are not redesigned are as follows:

1. The number of accidents cannot decrease, especially as a result of the driver being shocked by wild animals and the driver's visibility is disturbed. The impact varies, from minor injuries to loss of life.
2. The mystical issue in the research location will continue to develop in the community because there has not been any change in road conditions such as lighting and wild animals such as monkeys that resemble small humans.
3. Criminal action is difficult to suppress because the road conditions are dark, so it is quite risky to pass at night.
4. Local endemic fauna such as monkeys can be threatened by the population if traffic accidents involving wild animals are not prevented.
5. The tourists are still used to stopping on the side of the road so that it endangers other road users.
6. The habit of tourists giving food to monkeys on the roadside will attract other monkeys to come to the highway and can cause an accident.

4.4. New design impact

The positive impacts of implementing the new design are as follows:

1. Adding a sustainability aspect to road accessories design so that it can empower local animals without reducing the comfort of road users.
2. The number of accidents and crimes can be reduced because conditions are safer and lighter.
3. The mystical mindset of the local community can be replaced by reason slowly because of better lighting so that everything is visible.
4. The implementation of the stop prohibition can increase the comfort of road users as well as become an economic opportunity related to parking lots at tourist sites.
5. Road user compliance is increasing because of the no-stop signs so that traffic is more organized.
6. The behavior of the monkeys will not go wild and tend to be more controlled because feeding activities are not carried out in the highway area. [29]

The negative impact of implementing the new location design is regarding the comfortable concerns. The use of steel wires on the side of the bridge can reduce comfort in seeing the surrounding natural scenery, so tourists will be relocated from the main route of the new Gladak Perak Bridge to the old Gladak Perak Bridge which was built during the Dutch colonial era (This old bridge has been closed for vehicles to pass).

Sustainable design can reduce the negative impact on the environment. Without it, local fauna and local people will continue to be victims of traffic accidents. In addition, the lighting system that is not repaired immediately will endanger the safety of road users.

5. Conclusion

The road mitigation design in this study is a preliminary design, so that it requires further technical calculations to be applied in real terms. Through the design solutions that the authors provide, it is hoped that the accident problems at the research site can be resolved properly. In addition, the sustainable concept applied in the new design is expected to be able to preserve endemic nature and fauna.

Based on the results of this study, the suggestion for mitigation design applicators (Lumajang Regency Government) is to consider the positive impacts in making implementation decisions. The

funds spent at the beginning of the implementation of the new design will have a positive impact on the safety of road users, the preservation of endemic animals, and give an aesthetic impression, enabling the Gladak Perak Bridge to become an increasingly popular tourist destination in Indonesian society.

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