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Green technology as a strategy in managing the black spots in Siak Highway, Indonesia

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Green technology as a strategy in managing the black spots in Siak Highway, Indonesia

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Abstract. It was identified that the total traffic accidents in the highway section of Siak, Indonesia within the period of 2011 to 2015 were 1,208 events (2 accidents per 3 days). This accidents figure were considered relatively high and it need to mitigate. The aim of this research are to; (i) analyze the location of Black Spot in the Siak highway, and (ii) drawn a strategy reducing the traffic accidents based on green technology. This study identified that the black spot area was located in the STA 44 + 050 (with a value of the weighted index was 86 and an accident severity rate was 6.21), these values were relatively high. The road horizontal alignment condition at this location was highlighted as a sub-standard high way, consists of low visibility, numerous turning pads, minimum road signs, and minimum road shoulders width. The technical strategy was then drawn as follow; conducting regular road rehabilitation and maintenance, equipping road markings and the street lights as well as road safety facilities based on the green technology such as solar cell traffic lights, solar cell street lights and deploying police statues in reducing traffic accidents within the black spot areas.

1. Introduction

It is acknowledged that the traffic accidents are a serious problem, hence it must be managed in a systematic procedure [1], [2]. Traffic accidents may involve several factors, such as driver/human errors, vehicle failures, road infrastructure deficiency, and environmental condition uncertainty such as heavy rain, rock fall and gush [2]. According to the Indonesia's Law No. 22 of 2009 concerning the traffic and transportation regulation in Indonesia, the traffic accidents are defined as unexpected and unintentional events which may occur on the road and have resulted in human casualties and/or property loss [3-5]. Based on the Article 226 of Indonesia Law No. 22 of 2009, in order to improve traffic safety, the prevention of accident programs should be put into actions [6], [7]. Thus, it is necessary to get involve the top level of decision maker commitments, stakeholder participations, community participations, law enforcements and global partnerships to wholeheartedly committing in the improvement of the existing traffic safety in Indonesia as well as reducing accident rates systematically [7].

Based on the traffic accident data released by the Directorate of the Traffic of the Riau Province Police, it was calculated that the number of traffic accidents in the Riau area has been relatively high. In 2010 as many as 1,719 accidents occurred, with 763 people died. 994 people were seriously and slightly injured 1,356 people. In October 2011, the Riau Police Traffic Directorate has recorded as many as 1,672 traffic accidents occurred in Riau. There were 674 victims died, 1,176 serious injuries and 1,361 slight injuries. This means that almost every single day, there were two people have died as a result of the traffic accidents in Riau. The number of the traffic accidents in Riau Province is at 10th the highest one at the Indonesia national level [3, 8, 9].

One of a region prone to accident in Riau was Siak district, as this district connecting Minas-Kandis sub-districts passed by the national highway of Sumatra Island [3, 9] (Figure 1).

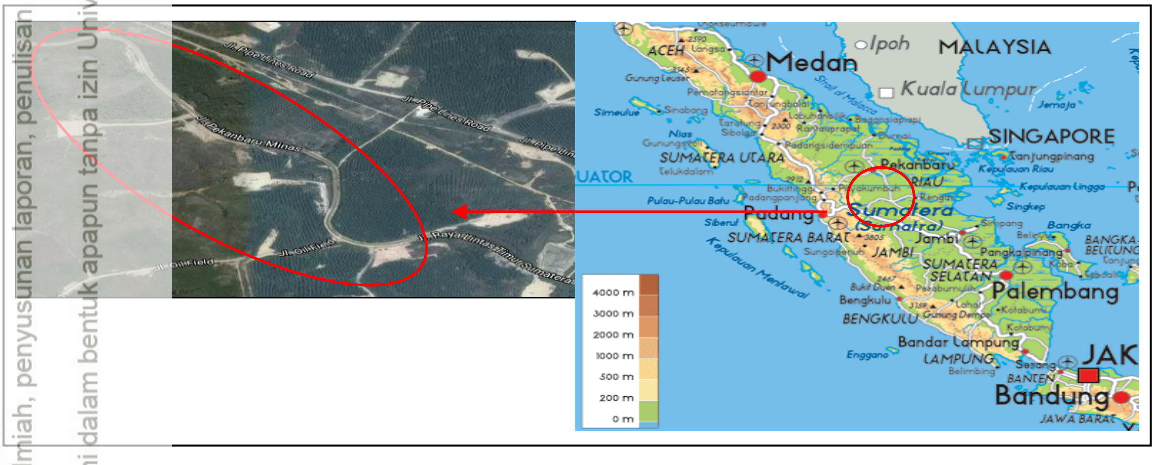


Figure 1. Research location at Siak, Riau, Indonesia.

It was identified that the total traffic volume from Minas sub-district = 2978 vehicle (45%), and from Kandis = 3640 vehicles (55%), with the total overall of 6618 vehicles [9] (Figure 2a). The dominant vehicles passing the highway were light vehicles (39%), and motorcycle (40%) (Figure 2b).

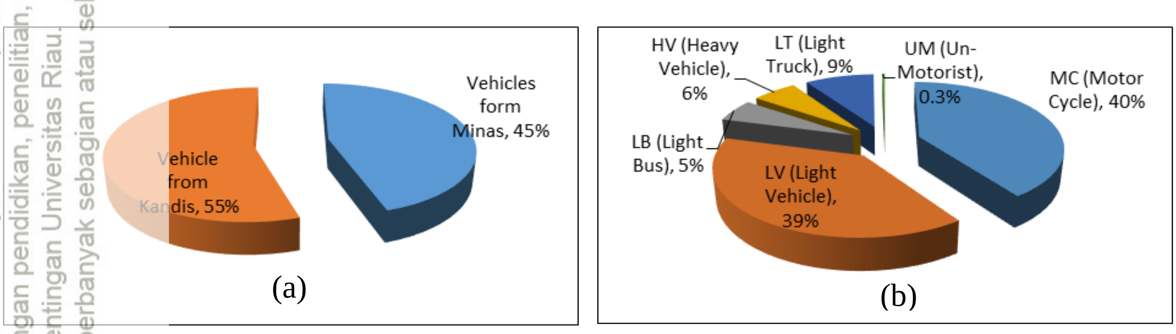


Figure 2. (a) Total traffic vehicles from Kandis and Minas, (b) Percentage of the vehicles source: Survey data, 2015.

The typical road segments may encompass a large number of sharp turnings (pads), limited visibility (no streetlights), and numerous patching holes. In anticipation of accidents on the road as the first step, it is a need to identify the accident-prone spots (black spots) (Figures 3a, b, and c)

(a) (b) (c)

Figure 3. (a) Sharp turnings (bends) without traffic signs and no streetlights, (b) the existing highway conditions with no road shoulder and no streetlights, (c) the existing patching holes. Source: Survey data, 2015.

Figures 3a, 3b and 3c shown the existing road turning and pavement conditions were need to repair. In order to repair the patch holes within the locations, the routine road maintenance programs can be conducted as regular bases.

The Figure 3 identified that there is no traffic signs and street lights on that locations. In the evening time, the locations were very dark and prone to traffic accident to occur.

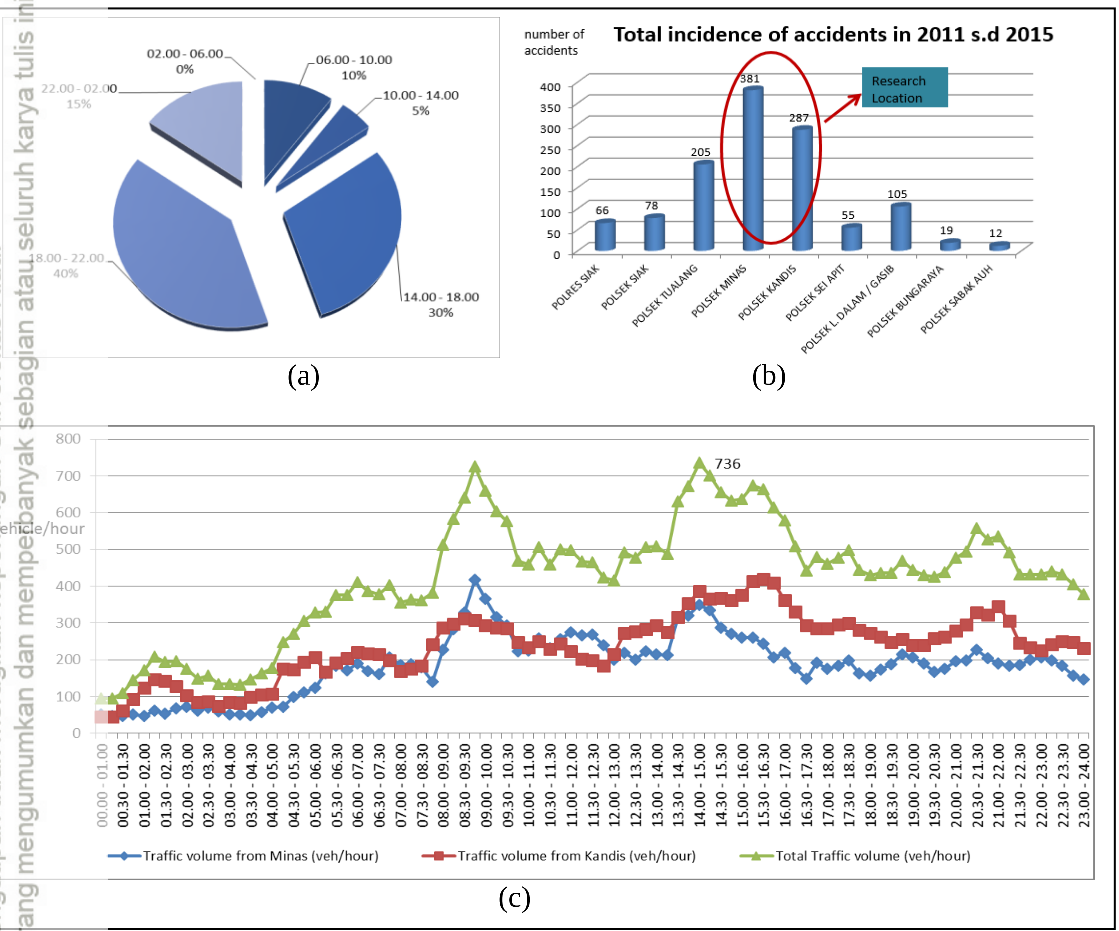


Figure 4. Traffic accident events in Siak, 2011-2015; (a) period of accident events, (b) the number of traffic accidents in Siak, (c) traffic volume (vehicle/hour). Source: Survey data, 2015.

Based on the period of accident events an evening time (18.00 - 22:00) (Figure 4a) was considered as the riskiest period of the traffic accident to occur in this location. This caused by the poor of street lights and as a consequence the road condition became very dark. Then at the evening time, some drivers have faced tiredness and physocological fatigue after long time driving during the day time period. The total traffic accidents in Siak within the five years period between 2011-2015 were calculated as 1,208 events [8, 9, 10] and 40% occurred in the evening time (18.00-22.00).

Figures 4b showed that 55% of traffic accidents in Siak was located at the Minas and Kandis Districts, contributing 381 and 287 accidents, respectively.

This analysis identified that the highest traffic volume within this highway was occurred during afternoon period of 14.00 – 15.00 with the number of traffic volumes of 736 vehicle/hour (Figure 4c). This traffic volume will be used to calculate a V/C ratio of this highway.

The highway capacity was calculated using PKJI 2014 formula [11]:

$$C = C_0 \times FC_W \times FC_{PA} \times FC_{HS} \quad (1)$$

C = Capacity
C_0 = Initial Capacity (3,000 passenger car/hour)
FC_W = Line width adjustment factors
FC_{PA} = Segregation of line direction adjustment factors
FC_{HS} = Obstacles aside and shoulder adjustment factors.

The highway capacity was calculated as follow;

C = 3,000 x 1.00 x 1.00 x 0.93 = 2.790 passenger car unit/hour

$$= \frac{736 \text{ pcu/hour}}{2{,}790 \text{ pcu/hour}}$$

The v/c ratio was calculated as v/c = 0.26

Hence, it was identified that v/c ratio was 0.26 (less than 0.8). It was determined that the traffic volume was relatively low compared to the existing highway capacity [11]. Thus, the vehicle speeds tend to be relatively high.

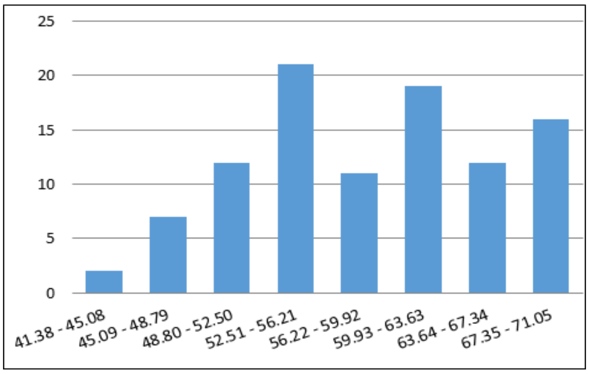


Figure 5. Private vehicle speed range in Siak, 2015.

Figure 5 shown that the average private vehicles travel speed passing this highway was 58 km/h. An approximately 16% of the vehicles travel speed was more than 67 km/h. Thus, the highway horizontal and vertical alignments, high pavement performance (Road Condition Index, RCI 8-10) and traffic signs required to be improved for accommodating the highway standard design for the designated speed limit at the average of 67 km/h.

The research objectives were to; (i) identify the location of black spot STA 43-45 in the Siak highway, Riau, Indonesia, (ii) analyze the accident occurrences, and (iii) develop an appropriate strategy to reduce the traffic accident events.

2. Methodology

A research methodology was developed into 5 stages; (i) identification and evaluation of the existing condition of the road alignment horizontal and vertical, hazardous conditions, encompassing; measuring the highway geometric conditions, horizontal curves, drainages, and road shoulders, pavement conditions, rutting, bleedings, potholes, cracks, and vertical curves, (ii) investigating traffic conditions, (iii) assessing the existing traffic signal conditions, road markings, and rail guards, and (iv) assessing black spots based on Weighted Severity Index (WSI) and Accident Rate (AR) approaches, then (v) this paper also give recommendations to manage the black spots.

The terminology of a black spot in a highway segment is defined as spot(s) that historically traffic accident has been regularly occurred [4], [5], [6], [12]. The black spot area in this highway was concentrated to 5 horizontal curves (bends) within 2 km road lengths (Figure 10). In order to identify the black spot areas, the calculated was performed using the Weighted Severity Index (WSI), as this WSI was commonly applied in many countries including India, Belgium, and Denmark [13, 14, 15]. The WSI was calculated as follow;

$$WSI = (5 \times K) + (3 \times GI) + (1 \times MI) \quad (2)$$

where; K = the number of persons killed,
GI = the number of injured persons,
MI = the number of non – serious injured persons.

The black spot areas were also identified using accident rate (AR). This was calculated using the following formula [15, 12,15]:

$$AR = \frac{ACC \times 1.000.000}{V \times 365} \quad (3)$$

where; AR = Accident rate; ACC = annual accident cases, and V = traffic volume.

2.1. Calculation of the black spot based on the weighted severity index (WSI) and the accident rate (AR)

Based on the WSI and Accident Rate, it is identified that the black spot location as the following calculation; The highest WSI located at KM 44+050, with WSI = (5 x 4) + (3 x 17) + (1 x 15) = 86 (Table 1).

Table 1. Weighted severity index

Location (STA)	Victim conditions K	GI	MI	WSI
43 + 250	1	11	9	47
43 + 600	2	4	16	38
44 + 050	4	17	15	86
44 + 400	1	9	4	36
44 + 950	2	2	1	17

where:

K = the number of persons killed,

GI = the number of injured persons,

MI = the number of non – serious injured persons.

The highest AR located at KM 44+050, with AR = 15 x 1,000,000/(6,618x365) = 6.21 (Table 2).

Table 2. Accident rate

Location (STA)	Accidents	Traffic Volume (vehicle)	Accident Rate (AR)
43 + 250	9	6618	3.73
43 + 600	7	6618	2.90
44 + 050	15	6618	6.21
44 + 400	11	6618	4.55
44 + 950	4	6618	1.66

Based on the results presented in the Table 1 and 2 above, it was identified that STA 44 + 050 and 43 + 250 were considered as the black spots as this highway segment yields the highest WSI compared to the other locations. Based on AR calculation, it was identified that STA 44 + 050 and 44 + 400 were considered as the black spots as this highway segment yields the highest AR. Hence, based on the results of WSI and AR, it was identified three black spots locations as follow; STA 44 + 050, 43 + 250, and 44 + 400.

This STA 44 + 050 was described as hilly road conditions, low visibilities, minimum traffic signs and markings, sharp bends, no road shoulders, no lightings, minimum guardrail, hence this STA was considered vulnerable to cause the higher road accidents at this highway segment (Figures 3 and 6).

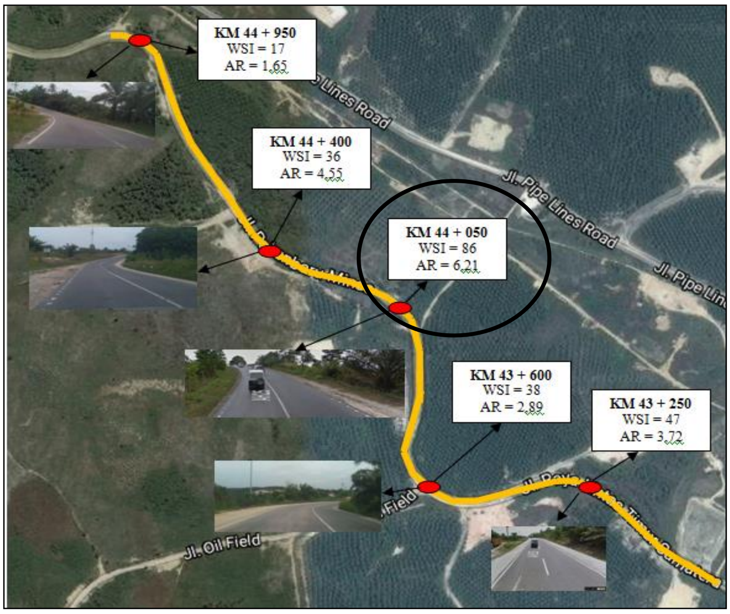


Figure 6. Location of black spots.

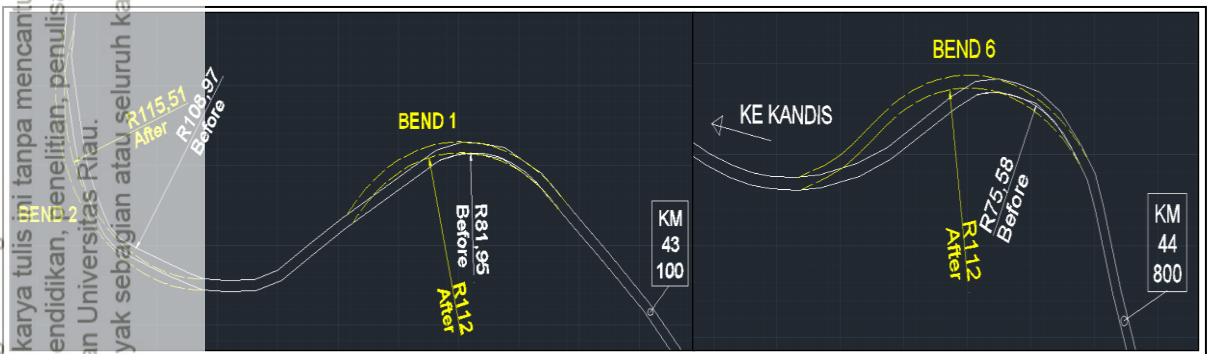
2.2. The horizontal alignment

Based on the field study, it was identified that existing highway encompasses six turnings (one bend was classified as a full circle (STA 43 + 600), and five bends as a spiral-circle-spiral type (STA 43 + 250, 44 + 050, 44 + 400, and 44 + 950).

Table 3. Identified types of turnings, and minimum radius of the bends.

No	Bends	Type	Locate (STA)	Radius (m)	R min (m) (PKJI)	R min (m) (Arithmetic)	Information
1.	Bend 1	S-C-S	43+250	81,95	1000	112	Not Eligible
2.	Bend 2	FC	43+600	108,97	1000	112	Not Eligible
3.	Bend 3	S-C-S	43+850	165,34	1000	112	Qualify
4.	Bend 4	S-C-S	44+050	114,22	1000	112	Qualify
5.	Bend 5	S-C-S	44+350	213,11	1000	112	Qualify
6.	Bend 6	S-C-S	44+950	75,58	1000	112	Not Eligible

Table 3 and Figure 6 showed that three sharp bends which were a maximum speed less than 60 km/h, this is because of the radius of each bend radius is smaller than the minimum radius standards of SCS bends of 112 meters. The horizontal geometry of this highway segment less than 112 m, thus did not comply the highway bend specification standards [12, 16, 17, 18,19]. Then, it is need to improve the existing horizontal radius alignment of these three turnings (Figure 7a and 7b).



(a) (b)

Figure 7. (a) A sharp turning of band 1 within the highway locations, (b) A sharp turning of band 6 (KM 44 + 950) within the highway locations.

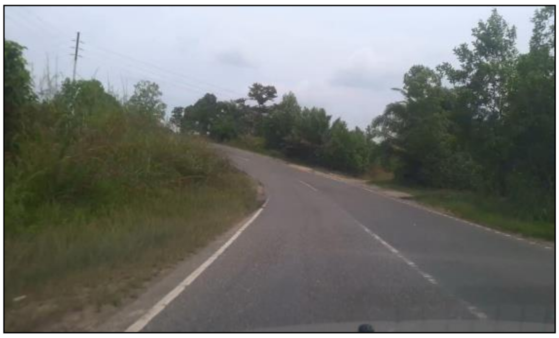


Figure 8. The vertical bends within the existing highway locations at KM 44 + 95.

For example, it was calculated that the existing Bend 1 horizontal radius was 81.95 m, Bend 2 was 108.97 m, and Bend 6 was 75.58 m. These three turnings need to be extended by the following dimensions 30.05 m, 3.03 m, and 36.42 m respectively to fulfil the radius turning minimum standards of 112 m.

An environmentally friendly approach for mitigating this turning issues can be applied by an improvement of the existing horizontal radius alignment may reduce centrifugal force so that the risk of sliding and sliding vehicles may be declined and as a consequence the number of accidents will be reduced [11].

2.3. Managing the black spot at STA 44+050

The existing of black spot condition at the STA 44 + 050 showed that this segment did not have road shoulder, poor street lighting, inadequate traffic signs, no guardrails, and road delineators. The vertical road curve was considered high (>30%) (Figures 8 and 9). Hence, these conditions were urgently required to be managed systematically.

Figure 9. The situation at STA 44+050 (Before rehabilitation).

This paper highlighted the technical aspects of managing the black spot located in the STA 44 + 050. This may include the constructing of road shoulder to accommodate vehicles to pull over. There is a need to install traffic signs boards such as 'Reduce Speed' sign boards (blinking), road safety fences (guardrails), road markings and street lighting, and installing policeman statues equipped with flashlights in order to warn the traffic users to be aware of their safety as showed in Figure 10 [19, 20, 21, 22].

Figure 10. A long climb segment (After rehabilitation).

In this study the overall traffic signs, street lighting and policeman statues equipped with flashlights will be proposed based on the green energy technology (Figure 10). Based on M. Richards, D. Carter, 2009 data the public lighting systems are considered as a major source of electricity consumption [23]. Approximately 3.19% of global electricity generation is used for lighting. This amount is greater than production of all hydro or nuclear plants and equals with the production from natural gas [23]. The depletion of fossil energy coupled with the climate change requires finding alternative energy production. Thus, alternative energies know a fast expansion [24].

Indonesia is ones of country that has a lot of solar energy resource and especially in Riau Province it can be seen in Figure 11, that the global horizontal irradiation of long-term average of annual sum is about 1600-1800 kWh/m^2 or about 4.5-5 kWh/m^2 for average daily sum [25]. The availability of solar energy resource in Riau Province is large enough for street lighting required.

The sun radiation in the form of shortwave radiation reaches the ground surface of earth may be estimated as a Global Horizontal Irradiance (GHI). The GHI in Indonesia was drawn as the following Figure 11 [26]. This GHI may indicate the potential of the solar photovoltaic (PV) technology may be applied in reducing electricity consumption in Indonesia.

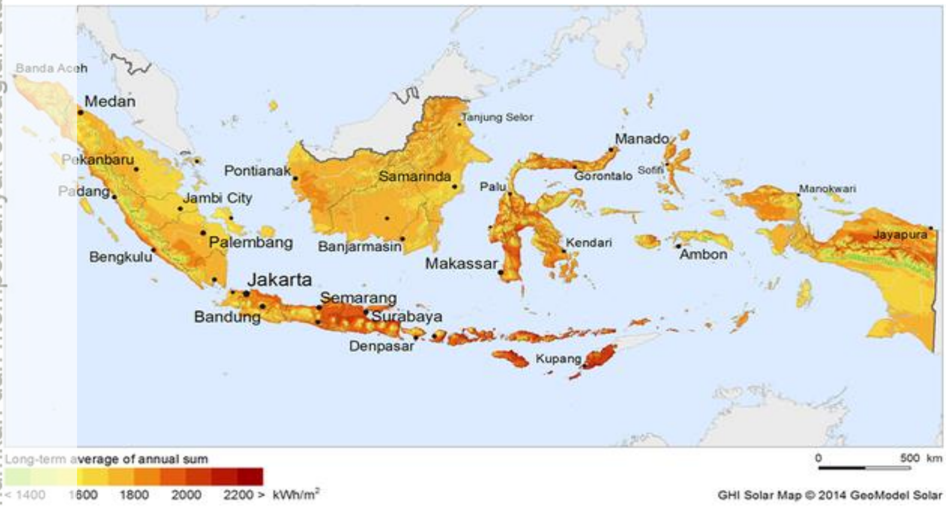


Figure 11. Global Horizontal Irradiation (GHI) in Indonesia [26].

For reducing the electricity consumption of street lighting, solar photovoltaic (PV) technology (Figure 11) is claimed as a solution for this part of electrical load because of its environmental advantages (e.g., cleaner, less emissions, and no fossil fuel) [26]. On the other hand, conventional street lightings with the solar photovoltaic usually utilize mercury lamps. The conventional street lighting utilizing mercury lamps consumed electrical power higher than 200 W per lamp in order to meet the street lighting requirement standards. The optical efficacy of light emitting diode (LED) has exceeded 72 lm/W in 2006. This implies that energy can be saved about 75%, as compared to mercury lamps used in roadway lighting [27]. These lamps were proposed to be applied in this case study.

The diagram of Photovoltaic Block System can be seen in Figure 12. This Photovoltaic System for accommodating the road way lightings as well as traffic signs would be applied within the black spots areas in Siak, Indonesia (2017).

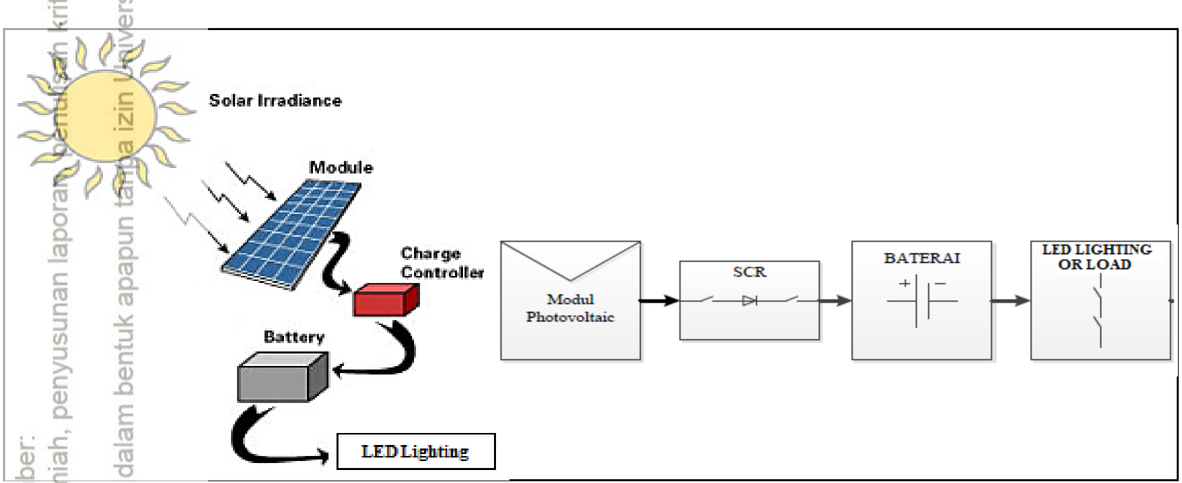


Figure 12. Schematic of photovoltaic system

3. Recommended strategy

There are 2 main strategies for reducing the number of accidents in the black spot area of KM STA 44 +050:

a. Accomplishing the road safety (horizontal alignment improvements) by the extension of the road existing horizontal radius alignment within the black spot areas.

a. Installing the green road traffic signs, road markings, street lightings and the policeman statues equipped with flashlights based on solar energy technology as show in Figure 13.

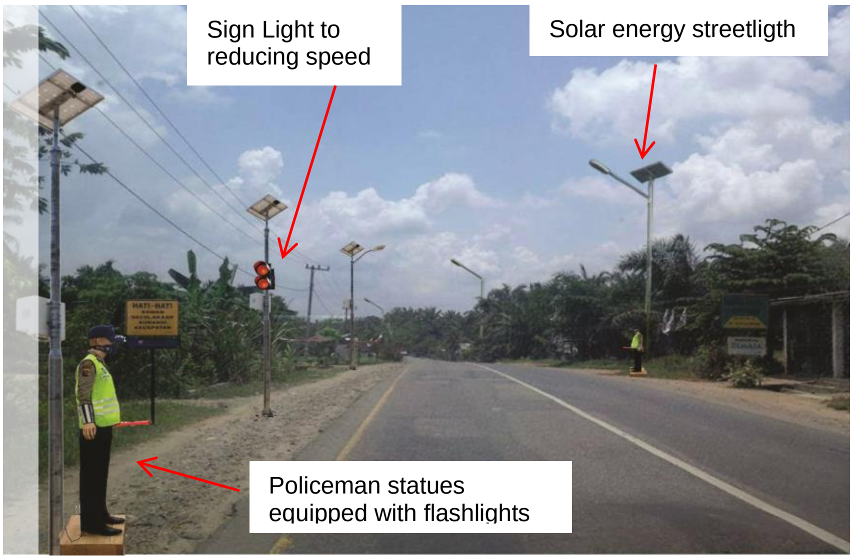


Figure 13. Recommended strategy to reducing traffic accident on the black spots in Siak highway by using green energy technology.

4. Conclusions

It was identified that there were three horizontal alignments out of six turnings did not meet the specification technical radius standards (r bends <112 m). These turnings were in need to repair. This research identified the black spots within this highway located at 44 + 050 as a case study. The conditions of these black spots were described as poor street lightings, inadequate traffic signs, no guardrails, no road delineators, and limited road shoulders as well as a number of patching holes. Thus, it is necessary to develop strategies in managing these black spots as follow; (i) rehabilitation of horizontal alignment, road pavement, and widening the existing road shoulders, (ii) installing traffic signs, road markings, street lighting, and guardrail delineator based on the green technology approaches.

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