AUSTRALIAN JOURNAL OF BASIC AND APPLIED SCIENCES

ISSN:1991-8178 EISSN: 2309-8414
Journal home page: www.ajbasweb.com

The Analysis Of *Safety Mirror* Placement For Traffic Safety At Trans-Sulawesi National Highway

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ARTICLE INFO

Article history:
Received 28 May 2017
Accepted 22 July 2017
Available online 26 July 2017

Keywords:
Safety Mirror, Safety, Traffic

ABSTRACT

Research was aimed (1) to analyze the placement, installation, and work mechanism of *Safety Mirror* along Majene-Mamuju RegenciesRoad in West Sulawesi, and also (2) to analyze the rate of traffic accident occuring along Majene-Mamuju Regencies Road after the placement of *Safety Mirror*. Methodology of research was quantitative. Type of research was *explanatory research* with cross-sectional approach.*Safety Mirror*mechanism involved the application of convex mirror and its precision was calculated with Gauss Formula. Result of research indicated several findings. (1) The location of placement and installation of *Safety Mirror* at Majene-Mamuju Axis Road was set from R 13 m to 20 m and from D 110.2^{o}to 7.16^{0}. However, it did not align with *Safety Mirror* mechanism as an instrument keeping the driver to stay alert against other vehicle in front of the curve at very wide sight field. Because the length of image was smaller, the vehicle in front of the curve was seen far away than its actual distance. The driver felt necessary to interpret the actual distance based on image sight from *Safety Mirror*. (2) The number of accident after *Safety Mirror* installation decreased by 35.48% in 5-year period. The presence of*Safety Mirror* helped the driver to predict the required sight distance, and it succesfully converted critical curve or dangerous bend into safe turnoff to prevent the occurence of traffic accident.

INTRODUCTION

Majene-Mamuju Axis Road at Trans-Sulawesi National Highway was vulnerable to the conflicting traffic occurence because this road had developed into a highway region connecting Mamuju, Central Sulawesi, North Sulawesi, and several sea harbors toward Kalimantan and Java. Some internodes along this national highway contained sharp curve and very challenging gradient of alignment. Gorge and steep slope ornamented one side of the road. Some trees and hills might cover up sight distance. Ascents and descents were quite frightening.All of these were the natural factors that must be highly attended in managing the traffic.

The length of Trans-Sulawesi Highway network was 597.78 km which connected surrounding districts and regencies. The general condition of road was usually good and ready to pass. However, anticipating the congestion and also the rush hour due to the passing vehicles from other regencies and other provinces, then the supporting structure was needed. One internode that was vulnerable to the conflicting traffic was Majene-Mamuju Axis Road at Km 347-Km 393.

To Cite This Article: Lambang Basri Said, Muhtar Tahir, Maryam Hapram, Qadriathi Athieq., The Analysis Of *Safety Mirror* Placement For Traffic Safety At Trans-Sulawesi National Highway. ***Aust. J. Basic & Appl. Sci.,*** *11(10): 41-47, 2017*

This internode had too many sharp curves which needed *Safety Mirror* to help vehicles passing it safely.

Gradient of the alignment or the curve was very challenging because one side of the road was gorge and steep slope. Other characteristic of this road included also trees and hills covering up sight distance, and the frightening ascents and descents. All of these were the natural factors deserving high priority in traffic management because of its potential capacity to cause traffic accident.

Accident rate at Majene-Mamuju Axis Road was the highest on 2001-2006 period with 11-20 occurences of accident. In other hand, the installation of *Safety Mirror* on 2007-2012 period had succesfully reduced accident rate.

Safety Mirror had similar function with usual mirror but it was made of Acrycarron/Acrylic that was known with anti-break and anti-fade characteristics. It remained strong to weather disturbances such as rain and heat. *Safety Mirror* was very ideal to be placed at (*Suwardjoko P. Warpani*, 2002):

1. Highway traffic, including at sharp curve, internode, and all locations where drivers' sight was very limited or hindered.
2. Office building environment.
3. Shopping center/ self-service market, being as surveillance device.

In the curve area, including ascents and descents, the effect of this device to reduce accident rate was not yet examined. In other hand, the field was vulnerable to accident and sometimes, few accidents caused high fatality.

Safety Mirror that was placed at Majene-Mamuju Axis Road (Dinas Perhubungan Sulawesi Selatan, 2002) had a round shape with diameter of 80 cm. Rear layer of the mirror was coated with iron. The pole was iron pipe. Its anchor was prepared from angle-bar, whereas the fastener involved galvanized material.

The Official of Highway Transport Traffic (DLLAJR) was not the only user of *Safety Mirror* but supermarket or self-service store also installed this device inside the room. The function of each usage was similar.

The function of *Safety Mirror* was to see the objects including thing, human, or animal, on the road when the position of the object could not be seen or hindered by another thing. The presence of *Safety Mirror* may reduce the possibility of collision which then helped smoothing the traffic and keeping the road user to pass the road easily (C.S.T. Kansil) (Ruly Astuti, I Suwabda, 2015).

Collision or accident usually occured at the curve which was unseen by the driver, or which was hindered by other thing. Driver from opposite direction must stay alert in passing the curve. Dangerous curve could produce human victim or material loss, and when the accident was happening at this curve, it might create a long congestion.

Any mirrors would reflect almost all beams fallen to its surface. The incoming beams were reflected based on beam reflection law proposed by Snellius (Snell Law). If mirror surface was considered, it was differentiated into flat, concave and convex (Sears. Zemansky, 1987). In general, concave mirror would enlarge or minimize the image depending on object position. Convex mirror produced a shadow smaller than original object. The image of flat and convex mirrors was always *virtual*, whereas concave mirror produced *real image* and *virtual imaage* depending on object position.

This writing was designed as a study of *Safety Mirror* placement, precisely concerning with traffic accident rate before and after the placement of *Safety Mirror*.

The objectives of research were (1) to analyze the placement, installation, and work mechanism of *Safety Mirror* along Majene-Mamuju Regencies Road in West Sulawesi, and also (2) to analyze the rate of traffic accident occuring along Majene-Mamuju Regencies Road after the placement of *Safety Mirror*.

Methodology of Research:

Research type was *explanatory research*with cross-sectional approach. Research variables were collected and measured at one time, meaning that some variables would be observed only once or examined in simultaneous way. Explanatory research was aimed to analyze relationships of one variable to another, or to ensure how a variable could influence other. (Umar, Husein, 2004)

Sample point was determined by selecting the internode where *Safety Mirror*existed, including its ascents or descents, or also by including the site with similar geometry to the internode but without *Safety Mirror*.Such locations were not given high priority by any stakeholders who had interest to install *Safety Mirror*, but the accident was still happening in those locations. Secondary data were obtained from the relevant agencies, and these data involved: traffic data, average daily traffic data (LHR), *Safety Mirror* data, accident data, location sketch (field sketch) and geometrical data. Primary data were obtained through field monitoring, which was concentrated upon the physical description of device/thing and site condition. Data were subjected to mathematical analysis to search for the proper spot where *Safety Mirror*must be situated, and the suitable position where *Safety Mirror*gave significant effect on reducing accident and fatality. It was assumed that other factors such as super-elevation slope, roughness, traffic sign and road marking, had also similar effect on the

accident rate. These factors would be helpful in analyzing accident condition because it provided possible description, tendency, and characteristic of the accident.

Result of Research:

West Sulawesi was geographically located at strategic position. The western part was bordered with Makassar Strait, whereas the north was bordered with Donggala Regency of Central Sulawesi Province and North Luwu Regency, eastern part with Tana Toraja Regency, and southern part with Pinrang Regency of South Sulawesi Province. The regional width of West Sulawesi Province was dominated by the land, and it reached 16,937.18 km^2. It contained low-lands and hills at 50-1500 m altitude.

Mamuju Regency had a regional width of 801,406 Ha. Administratively, the government of this Regency served 5 Districts, and each District comprised of 31 Sub-Districts/Villages. One Sub-District in Mamuju Regency was Tapalang District where *Safety Mirror* was placed. Majene Regency was 947.84 km^2 width. It consisted of 4 Districts, and one of them was Sendana-Malunda District where *Safety Mirror* was placed.

Geometric condition of internode from Majene Regency to Mamuju Regency was adequate. Its surface layer had been rehabilitated using hotmix asphalt. This internode became two-way traffic with hardness wide of 4.5–6 meters. The gradient of Majene-Mamuju Axis Road was averagely rated at 5-6% and the hills were 50-1500 m altitude. Higher road gradient influenced road user. The effect became quite obvious at the curve where vehicle tended to reduce its average speed. The smaller gradient of the road, the higher speed the vehicle wouldhave. Gradient was used as an important factor to install *Safety Mirror* at research location. Each mirror point had a road gradient ranging from 0 to 5 %.

Along Majene-Mamuju Axis Road, especially in *Safety Mirror* site, curvature radius length was below 700 meters. Based on road geometry, curvature radius length below 700 meters was assigned into a category of full circle. As a result, the curves in research location was becoming less ideal if it was reviewed from the perspective of road geometry planning. *Safety Mirror*was usually positioned at sharp curve, orat the place where the existing hills hinderingthe sight of the driver who entered the curve. It could be said that *Safety Mirror* was greatly helpful for road user.

Research location had 5 (five) pieces of *Safety Mirror*. One placement point of *Safety Mirror* along Majene-Mamuju Axis Road was at Km.347. The placement site was determined after considering sight distance and *Safety Mirror* work system.

Driver's security and convenience to have a clear sight field and also driver's easiness to be aware with driving situation were depending greatly on the distance the driver could see from original position. Road length ahead the vehicle that could be measured from driver point was called as *sight distance*. This sight distance gave some benefits such as: (1) to avoid the possibility of collision that might put vehicle and human into a risk of dangerous accident due to the presence of big vehicle parking by the street, the suddenly stopped vehicle, the pedestrian who crossed the street in rush, or the existence of animals on traffic lane; (2) to give opportunity to other vehicle to move at low speed using the adjacent path; and (3) to use it as the manual for traffic regualtor by placing properly targeted traffic signs at each road segment. (Teuku Hermansyah, et all, 2015).

Sight distance was needed to ensure whether a curve was feasible for *Safety Mirror* to be placed. If the curve had sight distance smaller than the standard, then this curve was feasible to be equipped with *Safety Mirror* to produce proper sight distance on the curve. (Sukirman, S. 1999)

Result of survey showed that sight distance (S_1) at Km.347 was 4-18 meters for vehicle with speed of 40 km. Any curves always decelerated traffic stream. Besides its vulnerability to the accident, it also slowed the journey length of vehicles. Based on the distance sight equation, there would be a speed of 40 km/hour and a responsiveness time of t = 2.5 seconds.

Table 1: The Placement of *Safety Mirror*

Sta./Km.	Speed (Vr)	Sight Distance (S)	Curve Length (L)	Radius (R)	Curvature Degree (D)
I / 347	40	45.8	60	16	89
II / 372	40	45.8	68	18	79.6
III / 376	40	45.8	63	13	110.2
IV / 386	40	45.8	65	20	71.65
V / 393	40	45.8	69	14	102.3

Source: Result of Survey

$S_1$was a distance (meter) the vehicle could afford after seeing a thing until it stopped by hitting the brake.

At the curve with *Safety* Mirror, the distance between vehicle and *Safety Mirror* was 50-100 meters (based on field survey). The ideal sight distance at the curve was 45.8 meters, meaning that *Safety Mirror* helped fulfilling the required sight distance and also succeed in coverting critical/dangerous curve into safe turnoff which could prevent the occurence of traffic accident.

Ideal sight distance was 45.8 meters, where D1 before the installation of Safety Mirror was 4-18 meters (critical/dangerous curve), whereas D1 after Safety Mirror was placed was 50–100 meters (safe curve).

Basically, *Safety Mirror*(Foster Bob, 2000) applied convex mirror concept. Gauss Formula was also applied to the mirror by the aim to measure the sight distance, respectively written as: $\frac{1}{S}+\frac{1}{S^1}=-\frac{2}{R}$

Where :

S :Distance of the thing to the mirror

S^1 :Distance of the shadow to the mirror

R :Radius of mirror curvature

Result of research indicated that after the installation of *Safety Mirror*, sight distance of the driver was 50-100 meters. By this number, it could be known how far was *Safety Mirror* performance when convex mirror was used. Based on this performance, minimum distance from *Safety Mirror* to the vehicle, and back to *Safety Mirror* again (sight distance) was then possibly estimated to obtain the actual width of the area.

Gauss Formula (Dhian A Sandy, et all, 2014) was $\frac{1}{S}+\frac{1}{S^1}=\frac{2}{R}$

Because convex mirror was used, then R (radius of curvature) must be negative (-) and therefore, the focus (F) was also negative,where F = $\frac{1}{2}R$ ….(Foster Bob, 2000)

In this case, $\frac{1}{S}+\frac{1}{S^1}=-\frac{1}{F}$ would describe the relationship between the distance of a certain thing and the distance of its image (shadow).

$$\frac{1}{S^1}=-\left[\frac{1}{F}-\frac{1}{S}\right]=-\left[\frac{S-F}{S\times F}\right]$$

$$S^1=-\left[\frac{S\times F}{S-F}\right] \quad (1)$$

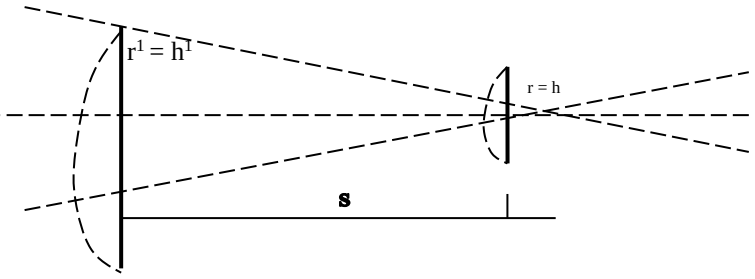

Fig. 1: Work System of *Safety Mirror*

It could be said that m = $\left|\frac{S^1}{S}\right|$ was the distance of image magnification (2)

Mirror width

$A=\pi\ r^2+\pi R_C^2$ (3)

R=Radius of mirror r = h

R_C=Radius of mirror curvature

Actual area width:

$A^1=\pi(h^1)^2$ (4)

$h^1=\sqrt{\frac{A^1}{\pi}}$ (5)

When mirror angle was similar to thing angle, and therefore:

$$\frac{r}{h^1}=\frac{R_C}{R_C+S}$$

Where : R_C = Radius of mirror curvature

S= Sight distance

$$h^1 = r\left[\frac{(R_C + S)}{R_C}\right] = r\left[1 + \frac{S}{R_C}\right] \quad (6)$$

Because $R_C = 2\ F_C$

and when F_C= Focus of mirror,

then Equation (6) was substituted into Equation (4)to become:

$$A^1 = \pi \cdot r^2\left[1 + \frac{S}{R_C}\right]^2 \quad (7)$$

or

$$A^1 = \pi \cdot r^2\left[1 + \frac{S}{2 \times F_C}\right]^2 \quad (8)$$

One of *Safety Mirror* placementpoint in the research location, precisely at Km347, had radius of mirror curvature (RC) of 85 cm. In several conditions, including: S= 50 meters = 5000 cm,F_C= 10 cm, R_C= 85 cm, r = 40 cm,therefore, it could be said that:

a. Area width that was absorbed by the mirror (A^1) could be counted from Equation (7)and thus, A^1 =17980166 cm^2.

b. Radius of actual area (h^1) could be estimated from Equation (5), and h^1=2393cm or around 24 meters.

c. Distance of image and its magnification could be calculated from Equation (1), and the result was S^1=-10 cm (image behind the mirror).

d. Distance magnification (m)could be known from Equation (2), and thus, m = 0.002 times.

Area width appearing on *Safety Mirror* would be:

$B = h^1 \times 2 = 24 \times 2 = 48$ meters.

B < 48 meters would mean that vehicle or thing after the curve could be seen (55 meters from *Safety Mirror*).

B > 48 meterswould mean that vehicle or thing after the curve could not be seen even after exceeding 55 meters from *Safety Mirror*.

Discussion:

Accidents were indeed happening at Majene-Mamuju Axis Road. Some area were vulnerable to traffic accident and vehicles must stay alert when passing the area. The accident vulnerable area was selected not only by estimating the rate of accident occuring at the area, but also by considering fatality rateof the accident. Fatality rate was estimated through the following description:

At Majene-Mamuju Axis Road (KM 47–KM 48) :

Number of accident = 5

Victim of accident:

a. Dead victim = 3

b. Heavy injured victim =-

c. Light injury victim = 1

Fatality rate copuld be as:N = (MD x 8) + (LB x 3) + (LR x 1)= 25

N-rate was shown in the following table.

Table 2: The Analysis on the Fatality Rate at Majene-Mamuju Axis Road

Accident Location (Km – Km)	Number of Accident	Victim			Fatality Rate (N)
		Dead	Heavy Injury	Light Injury	
01 – 03	4	4	-	-	38
03 – 04	1	10	-	-	80
06 – 07	2	2	-	-	20
18 – 21	2	1	1	-	14
36 – 37	2	1	-	4	14
41 – 42	1	-	-	2	2
47 – 48	5	5	-	1	25
53 – 54	1	-	-	3	3
58 – 59	2	2	-	-	20
70 – 71	1	1	-	-	10
82 – 83	1	-	-	2	2
87 – 89	2	-	7	-	21
93 – 94	1	1	-	-	10

Source: Result of Analysis on Fatality Rate

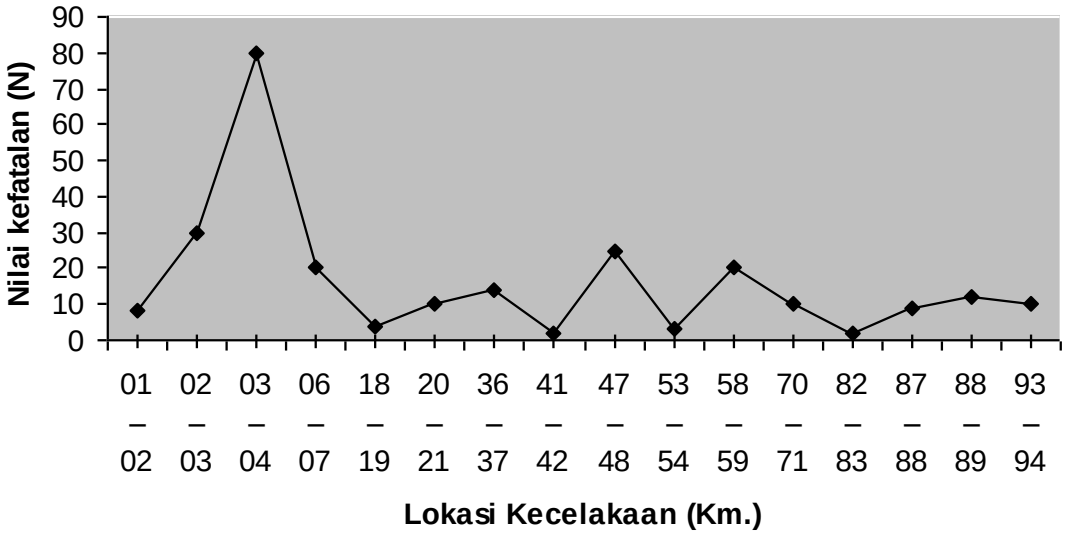

Fig. 2: Relationship Between Fatality Rate (N) and Accident Location

From the result of analysis above, it could be known the weight of accident rank by discerning the fatality rate of traffic accident that occured at Majene-Mamuju Axis Road. The highest fatality rate was found at Km 03-04 with N-rate of 80 and with great number of dead victims. The accident vulnerable area remained at Km 47-48 with five (5) cases of accident and with N-rate of 25.

Statistic instrument that was used to describe relative hardness rate was severity index (SI). Result of observation indicated that fatality rate of every accident at Majene-Mamuju Axis Road was counted as 0.58 death per accident. It was meant that every accident phenomenon had caused at least 1 people dead in two accidents at the last 5 years.

Conclusion:

As previously stated in the sections of result and discussion, this research provided conclusions as following.

The location to place and install *Safety Mirror* at Majene-Mamuju Axis Road was set from R 13 m to 20 m and from D 110.2^{o} to 7.16^{0}. However, it did not match with *Safety Mirror* mechanism as an instrument keeping the driver to stay alert against other vehicle in front of the curve at very wide sight field. The length of image was still smaller, and as a result, the vehicle in front of the curve was seen too far than its actual distance. The driver seemed being forced to interpret the actual distance based on image sight from *Safety Mirror*.

The number of accident at Majene-Mamuju Axis Road after *Safety Mirror* installation was reduced by 35.48% in 5-year period. *Safety Mirror* helped the driver to predict the required sight distance, and also succesfully converted critical or dangerous curve into safe bend which then preventedfurther occurence of traffic accident.

Traffic signs must be placed around 50 m before entering the accident vulnerable area. The sign could be warning sign, memorial post, road sign, and other kind of signs which could regulate road user to prepare themselves or to reduce their vehicle speed.

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