Designing a Model of the Early Warning System on the Road Curvature to Prevent the Traffic Accidents

Article · June 2022

Muhammad Nanang Prayudyanto
Universitas Ibn Khaldun Bogor

Arief Goeritno
Universitas Ibn Khaldun Bogor

Fadhila Muhammad Libasut Taqwa
Universitas Ibn Khaldun Bogor

International Journal of Safety and Security Engineering
Vol. 12, No. 3, June, 2022, pp. 291-298
Journal homepage: http://iieta.org/journals/ijsse

Designing a Model of the Early Warning System on the Road Curvature to Prevent the Traffic Accidents

Muhammad Nanang Prayudyanto[1], Arief Goeritno[2*], Safaruddin Hidayat Al Ikhsan[3], Fadhila Muhammad Libasut Taqwa[1]

[1] Civil Engineering Study Program, Faculty of Engineering and Science, Universitas Ibn Khaldun Bogor, Jalan Sholeh Iskandar km.2 Kedungbadak, Tanah Sareal, Bogor 16164, West Java Province, Indonesia
[2] Electrical Engineering Study Program, Faculty of Engineering and Science, Universitas Ibn Khaldun Bogor, Jalan Sholeh Iskandar km.2 Kedungbadak, Tanah Sareal, Bogor 16164, West Java Province, Indonesia
[3] Informatics Engineering Study Program, Faculty of Engineering and Science, Universitas Ibn Khaldun Bogor, Jalan Sholeh Iskandar km.2 Kedungbadak, Tanah Sareal, Bogor 16164, West Java Province, Indonesia

Corresponding Author Email: arief.goeritno@uika-bogor.ac.id

https://doi.org/10.18280/ijsse.120303

Received: 12 March 2022
Accepted: 22 May 2022

Keywords:
model of the early warning system, road curvature, road traffic safety, traffic accidents, and the radius of curvature

ABSTRACT

Road traffic safety in developing countries is a complex problem involving many factors such as humans, vehicles, structures, and the roads' environments. This study focuses on reducing traffic accidents for passenger busses, aiming to identify the causes and create a simple computer model to warn in areas like EWS using geometric road data. The survey was conducted at accident-prone locations and simulated the travel speed, road geometric, and traffic composition data. Results can be concluded that the rate is largely influenced by the radius of curvature, visibility, road gradient, and weather conditions. The concept of the EWS computer model was developed using web-based technology that can use to record the data instantly. The model had tested in another location to validate the field parameter and geometric road improvement.

1. INTRODUCTION

There are some definitions about an EWS that are used to guide a lot of actions of individuals, groups, and/or governments [1]. The EWS is a series of systems to notify the occurrence of natural events or the other forms [2, 3]. Its can be in the form of disasters or other natural signs or in the form of a number of traffic accidents [4-8]. The accidents on the traffic of highways or roads are events that have often occurred in the last decades' era. One of them is caused by the existence of the blind zone. Detecting the blind zone on the road curvature observed [9] from inside the vehicles is an essential function of the DAS that can effectively reduce the occurrence of traffic accidents [4-7, 9-11], fatal collisions [12], and has attracted unprecedented attention [5, 13]. The accident on the Intercity Buses happened in the sharp road curvature involving many passenger injuries and fatalities [14]. On the other hand, VNs have a huge potential to increase roadway safety and traffic efficiency [15].

Indonesia National Police data shows that number of death due to traffic accident has reached 31,234 people in 2010, which means that every one hour there are about 3 to 4 people dead from road traffic accidents [16, 17]. Rolison et al. mentioned three major factors that attribute to road accidents namely human-related factors, vehicle-related factors, and roadway-related factors [18]. American Association of State Highway and Transportation (AASHTO) [19] based on the USA traffic accident data, stated that roadway factors contribute by 3% of road accidents, whereas 34% is attributed by a combination of roadway-related factors and other factors [19]. However, since that the majority of road accidents factors are interrelated, it becomes complex to identify the certain cause of road accidents as the accidents occur due to a combination of several factors [20].

The relationship between geometric elements of road and road accidents has been developed to quantify [21-26]. Assessment using linear regression models showed unsatisfactory results as the properties of linear regression are normally distributed [27, 28], which can generate negative or non-discrete values of accident rates [21]. Another model, Poisson models were suggested [29] and used by Zhang et al. [30], for their consideration of random and sporadic data, in addition to easy estimation of variables relationships, however results can be overestimated or underestimated.

Horizontal road curve radius is a primary element of roads geometric design that is associated with horizontal curve design and it is related to traffic accidents as the smaller the curve radius, the higher the possibility of accidents to occur on roads. Assessment of travel speed shows that vehicle transverse stability which includes the slippage and overturns determines the curve radius value to be selected when designing road horizontal curves [31]. Zhang computed the radius mean and curvature degree for all categories used in his research and then he regressed them against the mean of accident rates in every category, his findings supported some previous studies which found and stated that the curve sharpness has a significant impact on the accident rates [30].

Many automotive manufactures now are using some kind of the DAS in different sections of the vehicle to minimize the several collision possibilities [7]. The manufactures started to implement prevention systems for rear-end collisions, to reduce the number of accidents and the crashworthiness. The rear vehicle position is monitored with the help of radar sensors, which are located directly behind the rear bumper [6]. At least one or more radar sensors detect vehicles approaching from behind which are on direct collision course to the vehicle up to a distance of approximation to 80-100 meters and a relative speed of approximation to 60 km/h. The same radar sensors are also used for the blind spot warner on both vehicle sides too. This system is used to prevent collision of vehicles while overtaking.

The elements of geometric design play a big role to affect of the traffic accidents rates [21-26]. In Indonesia, research and assessment of road geometric was conducted in several cities, such as at Sungai Raya Kepulauan, West Borneo [32], at Magelang, Central Java [33], at Malang, East Java [34], at Tawangmangu, Central Java [35], at Luragung-Cidahu, West Java [36], and on the southern Java ring road [37]. Based on that, to improve the traffic safety on the roads, the drivers must be warn when approaching the road curvature and adjusting the travel speed to mitigate accidents occurrence and severity on roadways.

The EWS made in this first stage is a model to get the minimum radius and maximum permissible speed on an gradient (sag or step)/curvature. Many parameters are used as input to get these values, such as road curvature data, travel speed, traffic analysis, and others. This maximum permissible speed becomes a key in the future to determine whether an object that passes through the gradient/curvature is at a safe rate or needs to be warned to adjust the speed according to the permissible speed. In this built EWS model, the application will process the speed data to be simulated and compare it automatically with the maximum speed from calculations and geometry analysis results. The application will provide a safe sign or warning against the rate.

This EWS database also includes the road safety facilities for survey data. The output of the EWS system built is not only for road users but also for relevant stakeholders to monitor and determine the infrastructure feasibility of the bend/incline. To improve the road design [14, 15], the creation of software on the EWS is really important [4-7], through research objectives, i.e. (i) data validation about the road condition, traffic volume, and bus velocity at the Emen Hills (Subang District) and the Tapalkuda Curvature (Cianjur District), and (ii) the performance of EWS.

2. MATERIALS AND METHODS OF RESEARCH

2.1 Materials of the research

The road curvature data, travel speed, traffic analysis and road safety facilities are input for the automatic model development. This system involves many parties' data inventory. The output of the EWS is an assessment of the severity of conditions against accident hazards. Using traffic management to give better geometric recommendations through i) improvement of road direction, ii) improvement of road safety facilities, iii) road grade improvement, iv) travel demand control, and v) progress of road curvatures and preparation of new road geometrics.

The detection distance depends on the position, the geometry and the relative speed between the two vehicles. The system's main task is the visual warning of the upstream traffic using high-frequency flashing warning lights. By law, the first visual warning level only can be activated for a TTC of less than 1.4 seconds [6]. The vehicle is preparing for an imminent crash at a second warning level. The belt systems inside the car are tensioned to keep the belt slack as small as possible. In addition, when the vehicle is at a standstill, it increases the braking pressure and thereby blocks the vehicle's brakes. This complete blocking of the brakes is intended to help prevent a movement in the positive X direction in the event of a collision and to avoid accidents with other road users. Depending on the manufacturer, the backrests are also moved into a vertical position, and windows and sunroofs are closed.

2.2 Methods of the research

The research method is an algorithm of a researcher for conducting the research that is carried out in the form of stages for achievement and accordance with the objectives of research [38-41]. The flowchart of the research methods is shown in Figure 1.

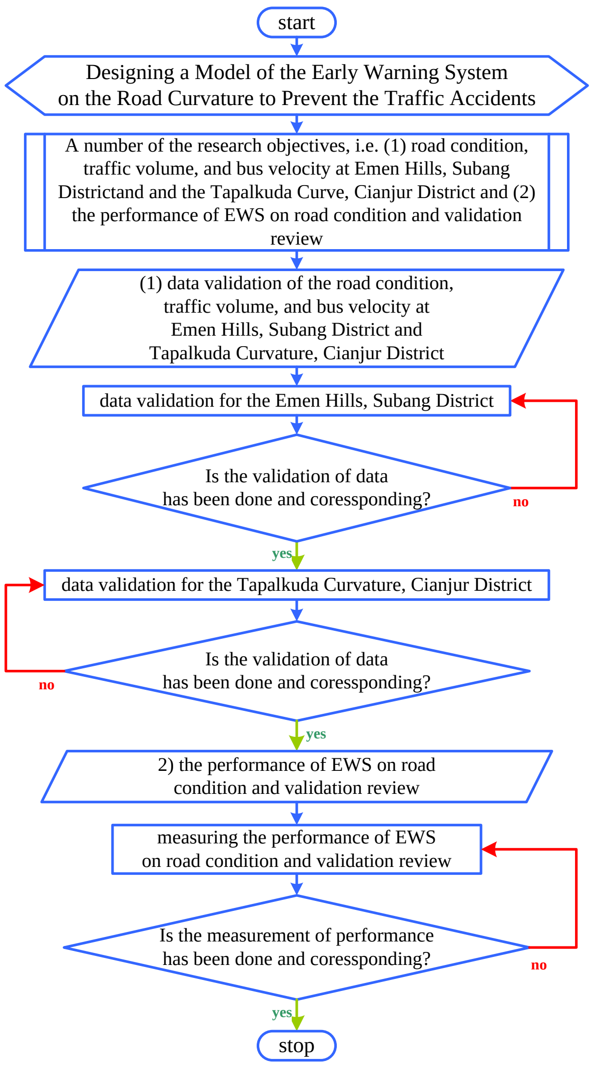


Figure 1. Flowchart of the research methods

Based on Figure 1 can be explained that for elaborating the data validation, including (a) road condition and (b) traffic measurement analysis, namely (i) results of the measurement of traffic volume and bus velocity at Emen Hills (Subang District), (ii) results of the measurement of traffic volume and bus velocity at the Tapalkuda Curvature (Cianjur District). The elaborations of the EWS performance are road condition and validation review of the EWS.

3. RESULTS AND DISCUSSIONS

3.1 Validating the measurement data

Based on the data validation conducted, two assessments have obtained the road condition and analysis of the traffic measurement. Existing the data validation of the road geometric and facilities, long and cross-section, and the radius of curvatures at the Emen Hills (Subang District) and the Tapalkuda Curvature (Cianjur District) are shown in some tables and figures. The characteristics of road geometrics are shown in Table 1; the road facilities are shown in Table 2, the long section and the radius of curvatures at the Emen Hills (Subang District) are shown in Figure 2, the cross-section characteristics at the Emen Hills (Subang District) is shown in Table 3, the long section of Sta. 0+000 to Sta.0+450 and the radius of curvatures at the Tapalkuda (Cianjur District) is shown in Figure 3, and the cross-section characteristics at the Tapalkuda Curvature (Cianjur District) are shown in Table 4.

Based on Figure 4, the measurements of bus velocity at the Emen Hills (Subang District) are the average space velocity of bus-type vehicles and are also influenced by the slope of the observed road segment. It obtained the highest average speed on downhill road conditions at the Emen Hills (Subang District) toward the Ciater at Sta. 0+350 to Sta. 0+370 with speed up to 60 km/h, and the lowest average rate occurs on the road with the smallest radius, i.e., the Sta. 0+390 to Sta. 0+410 with an average speed of 15 km/h. In uphill road conditions, the average vehicle speed is 8 to 23 km/h. The space velocity at the Emen Hills is shown in Table 5.

Table 1. The characteristics of road geometric

No.	Parameter	Location	
		Emen Hills, Subang District, West Java	Tapalkuda Curvature, Cianjur District, West Java
1	Road Classification	Arterial, Provincial Road	Arterial, National Road
2	Length of Critical Section	200 meters (Sta. 0+300 – Sta. 500)	60 meters (Sta. 0+180 - 0+240)
3	Road Width	14 -16 meters (2 lanes two ways)	7 – 8 meters (2 lanes two ways)
4	Shoulder	1 meter on both sides, unpaved	1 meter on both sides, concrete pavement
5	Road Widening in the Curvature	4 – 6 meters	None
6	Median	Road Marking	Road island, Sta. 0+275 – Sta. 0+350
7	Vertical Gradient	10% - 12%	7% - 8%
8	Maximum Superelevation	10%	10%

Table 2. The road facilities

No.	Road Safety Facilities	Location	
		Emen Hills, Subang District, West Java	Tapalkuda Curvature, Cianjur District, West Java
1	Climbing Lane	Available	No
2	Emergency Stop Lane	Available	No
3	Road Marking	Available	Available
4	Drainage	Available	Available
5	Road Signs	Improper	Available
6	Street Lighting	Available	Available
7	*Guard rail*	Not Available	Available
8	*Concrete barrier*	Not Available	Available

Table 3. The cross-section characteristics at the Emen Hills (Subang District)

Sta.	Segment Length (m)	Curvature Type	Radius (m)	Gradient	
				Left	Right
0+000	50	SL		-5%	-4%
0+050	50	SL		-8%	-5%
0+100	50	SC		-8%	+10%
0+150	50	C	62.5	-2%	+8%
0+200	50	C	62.5	-8%	+4%
0+250	50	C	62.5	-14%	+4%
0+300	50	SC		-7%	+7%
0+350	50	SC		-2%	-3%
0+370	20	C	24.3	+6%	-4%
0+390	20	C	24.3	+7%	-5%
0+410	20	C	24.3	+11%	-11%
0+430	20	C	24.3	+11%	-9%
0+450	20	C	24.3	+4%	'-6%
0+475	25	C	24.3	+4%	'-5%
0+500	25	SC		-9%	-2%
0+525	25	C	48.1	-7%	+9%
0+550	25	SC		-4%	+3%
0+575	25	SL		-4%	-2%
0+600	25	SL		+3%	-6%

Abbreviations in the table: Sta. = Station; SL = Straight Line; C = Circle; SC =Spiral Circle.

Figure 2. The long section and the radius of curvatures at the Emen Hills (Subang District)

Figure 3. The long section of Sta. 0+000 to Sta.0+450 and radius of curvatures at the Tapalkuda Curvature (Cianjur District)

Table 4. The cross-section characteristics at the Tapalkuda Curvature (Cianjur District)

Sta.	Segment Length (m)	Curvature Type	Radius (m)	Gradient	
				Left	Right
0+000	50	SL		-4%	-5%
0+050	50	SC		-2%	-5%
0+100	50	C	164.4	-4%	-9%
0+150	50	SC		-4%	-8%
0+175	25	SL		-1%	-9%
0+200	25	C	19.9	+9%	-13%
0+225	25	C	19.9	+7%	-16%
0+250	25	C	19.9	+4%	-14%
0+275	25	S		-9%	-9%
0+300	25	S		-5%	+10%
0+325	25	C	43.4	-5%	+11%
0+350	25	S		-4%	+2%
0+375	25	SL		-4%	-4%
0+425	50	SL		-5%	+2%

Abbreviations in the table: Sta. = Station; SL = Straight Line; C = Circle; SC =Spiral Circle.

Table 5. The space velocity at the Emen Hills

Sta.	The segment length (m)	Toward to the Ciater		Toward to the Lembang	
		m/s	km/h	m/s	km/h
300-350	50	14.11	50.80	2.19	7.90
350-370	20	16.72	60.19	9.56	34.40
370-390	20	10.92	39.31	4.42	15.91
390-410	20	4.24	15.27	2.98	10.73
410-430	20	4.49	16.17	4.86	17.49
430-450	20	11.20	40.31	5.56	20.01
450-470	20	4.52	16.27	5.95	21.43

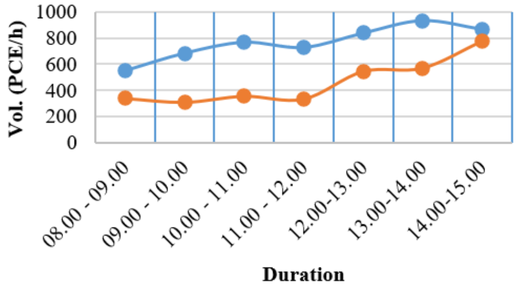
The results of the measurement of the traffic volume are based on the observations that have been made in the Tapalkuda Curvature (Cianjur District) and obtained 15,000 passenger cars per day so that it can cause some curves. The data curves of traffic volume at the Tapalkuda Curvature toward the Puncak to the Cianjur District and totals are shown in Figure 5.

The bus velocity measurement results at Tapalkuda Curvature (Cianjur District) are shown in Table 6.

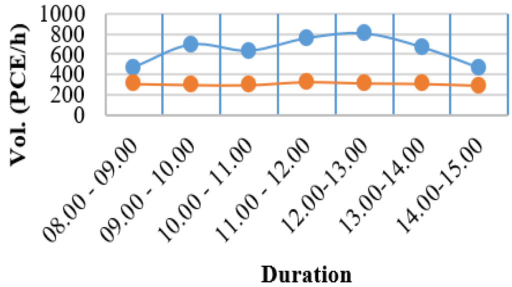
Based on Table 6, the results of observations at the Tapalkuda Curvature (Cianjur District) show that the average space velocity of bus-type vehicles is also influenced by the slope of the observed road segment. It obtained the highest average speed on downhill road conditions towards Cianjur District at Sta. 0+000 to Sta. 0+150 with a speed of up to 58 km/h. The lowest average rate occurs on the road with the smallest radius, namely the Sta. 0+15 to Sta. 0+375, with an average speed up to 15 km/h. In uphill road conditions, the lowest vehicle speed occurred at Sta. 0+275.

Table 6. The results of measurement of bus velocity at Tapalkuda Curvature (Cianjur District)

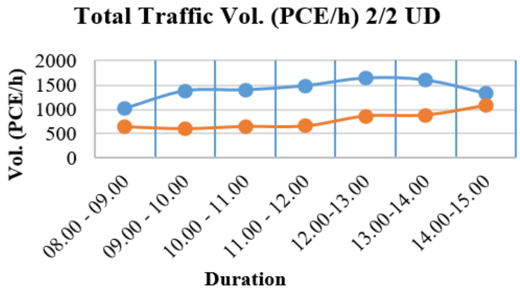
Sta.	Segment Length (m)	Toward to the Cianjur District		Toward to the Puncak	
		m/s	km/h	m/s	km/h
0-150	150	16.10	57.95	11.82	42.55
150-225	50	8.02	28.87	6.51	23.44
225-275	50	10.14	36.48	6.00	21.60
275-325	50	10.97	39.50	8.94	32.18
325-375	50	10.45	37.63	7.53	27.09
375-475	100	14.21	51.16	9.80	35.27



#a) traffic volume at the Emen Hills toward the Ciater



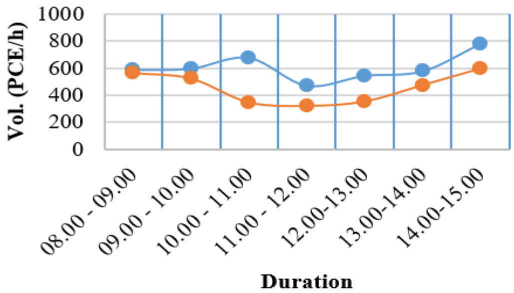
#b) traffic volume at the Emen Hills toward the Lembang



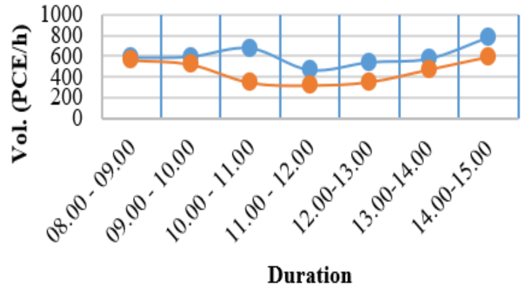
#c) total traffic volume at the Emen Hills

------: Day -1
------: Day - 2

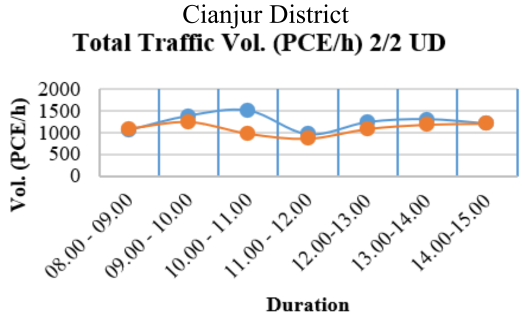
Figure 4. The data curves of traffic volume at the Emen Hills toward the Ciater, to the Lembang, and the total traffic volume



#a) traffic volume at the Tapalkuda Curvature to the Puncak



#b) traffic volume at the Tapalkuda Curvature toward to the Cianjur District



#c) a total traffic volume at the Tapalkuda Curvature

------: Day -1
------: Day - 2

Figure 5. The data curves of traffic volume at the Emen Hills toward the Puncak, toward the Cianjur District, and the total traffic volume

Table 7. The characteristics of geometric data

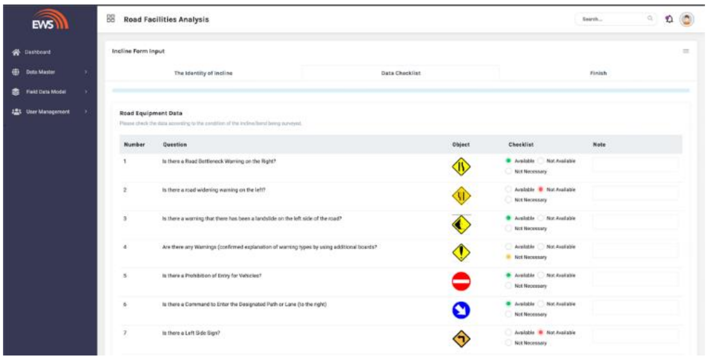
No.	Parameter	Lembah Koi Curvature, Cianjur District, (West Java)
1.	Road Classification	Arterial Road, National
2.	Length of Critical Section	100 meters (STA 0+150 – 0+250)
3.	Road Width	7 – 8 meters (2 lanes two ways)
4.	Shoulder	1 meter on both sides, concrete pavement
5.	Road Widening in the Curvature	None
6.	Median	None
7.	Vertical Gradient	5% - 7%
8.	Maximum Superelevation	14%
9.	Road radii	37 meters

3.2 Performance of the EWS

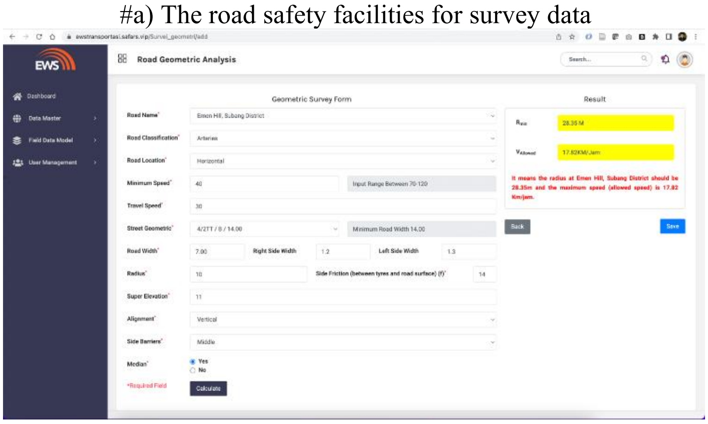
The display of geometric tracing at Lembah Koi, Cipanas Regency, Cianjur District is shown in Figure 6, the characteristics of geometric data are shown in Table 7, and the display of the initial EWS modeling application is shown in Figure 7.

Based on Figure 6, Table 7, and Figure 7, it can be explained that during the validation of the EWS program, the system obtained the following note that the EWS program that has been developed can still be improved, both in terms of appearance, the UI, ease of use (user-friendly system), as well as in the data processing process. Based on the note and findings above, several recommendations that can submit included the following, namely i) filling and presenting traffic data based on traffic counting results, ii) weighting of AEK, iii) geometric calculations on long incline/descending, iv) hotline service, v) adding a new account online (for the general public), and vi) the general public (users) are allowed to add new location data, equipped with existing photos in real-time.

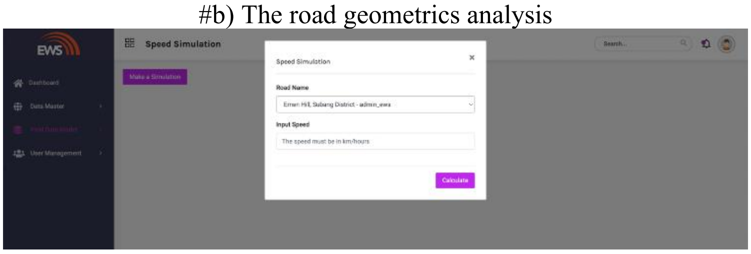
Figure 6. The geometric tracing at Lembah Koi, Cipanas Regency, Cianjur District



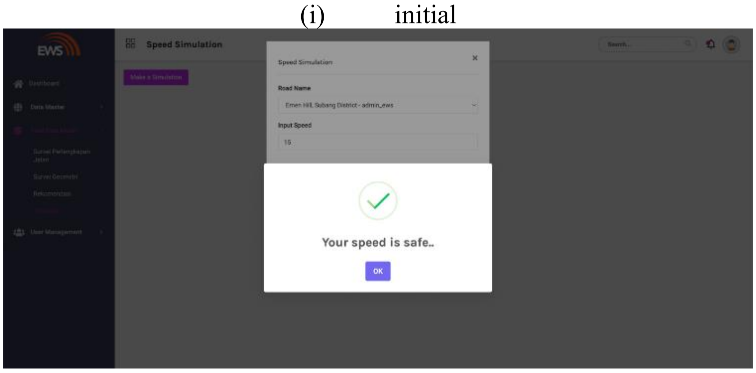
#a) The road safety facilities for survey data



#b) The road geometrics analysis



(i) initial



(ii) end

#c) Speed simulation

Figure 7. The display of the initial EWS modeling application

4. CONCLUSION

The effort to reduce traffic accidents in road curvature in this research is dedicated to passenger busses, aiming to identify the causes and create a simple computer model to warn called EWS. The survey was conducted at accident-prone locations on the arterial roads and simulated travel speed data, geometric and traffic composition data. One site has an extremely sharp horizontal alignment, and another has a critical horizontal and vertical alignment. Based on the results, the speed is largely influenced by the radius of curvature, visibility and road gradient, and weather conditions. The traffic is estimated at 15,000 cars/day with traffic speeds ranging from 7.90 to 60.19 km/h; however, bus speed can run to 57.69 km/h, assuming that it cannot control the speed when entering the sharp curvature. The EWS program developed can be used to model to warn the bus driver since the first time can use the web-based technology to record the data instantly. The improved model should be proven and tested in other locations to validate the field parameter and geometric road improvement.

REFERENCES

[1] Saadeldin, M., Mazen, S., Ezzat, E., Zaher, H. (2014). Using a Multi-Criteria Approach in Early Warning Information Systems (MCEWIS). In New Perspectives in Information Systems and Technologies, 1: 399-410. https://dx.doi.org/10.1007/978-3-319-05951-8

[2] Mulero-Chaves, J., De-Cola, T. (2017). Public warning applications: Requirements and examples. Wireless Public Safety Networks 3, ScienceDirect, 1-18. https://dx.doi.org/10.1016/b978-1-78548-053-9.50001-9

[3] Guerrero-Ibáñez, J., Zeadally, S., Contreras-Castillo, J. (2018). Sensor technologies for intelligent transportation systems. Sensors, 18(1212): 1-24. https://dx.doi.org/10.3390/s18041212

[4] Pooja, P.R., Hariharan, B. (2017). An early warning system for traffic and road safety hazards using collaborative crowdsourcing. 2017 International Conference on Communication and Signal Processing (ICCSP). https://dx.doi.org/10.1109/iccsp.2017.8286570

[5] Lin, Y.Y., Hsiung, P.A. (2017). An early warning system for predicting driver fatigue. 2017 IEEE International Conference on Consumer Electronics – Taiwan (ICCE-TW). https://dx.doi.org/10.1109/icce-china.2017.7991106

[6] Bidinger, C., Bogenberger, K, (2017). Early warning system for emergency vehicles to prevent rear-end collisions using radar sensors of current driver assistance systems. International Conference on Intelligent Transport System in Theory and Practice, Mobil TUM. 1-15.

[7] Shen, B., Zhang, Z., Liu, H., Li, S., Zhao, L. (2018). Research on a conflict early warning system based on the active safety concept. Journal of Advanced Transportation. 2018(Article ID 8372108): 1-11. https://dx.doi.org/10.1155/2018/8372108

[8] Teimouri, F., Ghatee, M. (2020). A real-time warning system for rear-end collision based on a random forest classifier. Journal of Soft Computing in Civil Engineering, 4(1): 49-71. https://dx.doi.org/10.22115/scce.2020.217605.1172

[9] Han, L., Zheng, P., Li, H., Chen, J., Hua, Z., Zhang, Z. (2022). A novel early warning strategy for right-turning blind zone based on vulnerable road users detection. Neural Computing and Applications. http://dx.doi.org/10.1007/s00521-021-06800-2

[10] Piao, J., McDonald, M. (2008). Advanced driver assistance systems from autonomous to cooperative approach. Transport Reviews, 28(5): 659-684. https://dx.doi.org/10.1080/01441640801987825

[11] Bengler, K., Dietmayer, K., Färber, B., Maurer, M., Stiller, C., Winner, H. (2014). Three decades of driver assistance systems review and future perspectives. IEEE Intelligent Transportation Systems Magazine, 6(4): 6-22. https://dx.doi.org/10.1109/MITS.2014.2336271

[12] Hasanzadeh, J., Amiresmaili, M., Moosazadeh, M., Najafi, F., Moradinazar, M. (2013). Implementing a weather-based early warning system to prevent traffic accidents fatalities. World Applied Sciences Journal, 24(1): 113-117. http://dx.doi.org/10.5829/idosi.wasj.2013.24.01.746

[13] Werneke, J., Vollrath, M. (2013). How to present collision warnings at intersections? A comparison of different approaches. Accident Analysis & Prevention, 52: 91-99. https://dx.doi.org/10.1016/j.aap.2012.12.001

[14] Zuraida, R., Abbas, B.S. (2020). The factors influencing fatigue related to the accident of intercity bus drivers in Indonesia. International Journal of Technology, 11(2): 342-352. https://dx.doi.org/10.14716/ijtech.v11i2.3792

[15] Najada, H.A., Mahgoub, I. (2016). Anticipation and alert system of congestion and accidents in VANET using Big Data analysis for Intelligent Transportation Systems. 2016 IEEE Symposium Series on Computational Intelligence (SSCI). https://dx.doi.org/10.1109/ssci.2016.785009

[16] Directorate General of Land Transportation, Ministry of the Transportation Republic of Indonesia. (2011). National Plan on Road Safety 2011-2035.

[17] Yahya, M.N., Faulks, I.J., Hambleton, P., Wass, C. (2013). Development of an integrated road safety management system in Indonesia: Traffic police as lead agents in a Safe System approach. Journal of the Australasian College of Road Safety, 24(2): 28-38.

[18] Rolison, J.J., Regev, S., Moutari, S., Feeney, A. (2018). What are the factors that contribute to road accidents? An assessment of law enforcement views, ordinary drivers' opinions, and road accident records. Accident Analysis and Prevention, 115(2018): 11-24. https://doi.org/10.1016/j.aap.2018.02.025

[19] Technical Committee on Geometric Design. (2018). The Green Book: A Policy on Geometric Design of Highways and Streets, 7th ed. Washington, DC: American Association of State Highway and Transportation Officials (AASHTO).

[20] Lord, D., Qin, X., Geedipally, S.R. (2021). Identification of hazardous sites. Highway Safety Analytics and Modeling. Science Direct, 259-297. https://doi.org/10.1016/B978-0-12-816818-9.00001-9

[21] Coruh, E., Bilgic, A., Tortum, A. (2015). Accident analysis with aggregated data: The random parameters negative binomial panel count data model. Analytic Methods in Accident Research, 7(C): 37-49. https://dx.doi.org/10.1016/j.amar.2015.07.001

[22] Soehodho, S. (2017). Public transportation development

and traffic accident prevention in Indonesia. IATSS Research, 40(2): 76-80. https://dx.doi.org/10.1016/j.iatssr.2016.05.001

[23] Sugiyanto, G. (2017). The cost of traffic accident and equivalent accident number in developing countries (Case study in Indonesia), ARPN Journal of Engineering and Applied Sciences, 12(2): 389-397.

[24] Jusuf, A., Nurprasetio, I.P., Prihutama, A. (2017). Macro data analysis of traffic accidents in Indonesia. Journal of Engineering and Technological Sciences, 49(1): 132-143. https://dx.doi.org/10.5614/j.eng.technol.sci.2017.49.1.8

[25] Islam, Md.H., Hua, L.T., Hamid, H., Azarkerdar, A. (2019). Relationship of accident rates and road geometric design. IOP Conference Series: Earth and Environmental Science, 357: 012040. https://doi.org/10.1088/1755-1315/357/1/012040.

[26] Kriswardhana, W., Hasanuddin, A., Palestine, I.M. (2020). Modeling the road traffic accident rate and road geometric parameters relationship. AIP Conference Proceeding, 2278: 020003. https://doi.org/10.1063/5.0014530

[27] Ma, L., Yan, X. (2014). Modeling zonal traffic accident counts with the regression under zero-adjusted inverse gaussian distribution. Procedia – Social and Behavioral Sciences, 138: 452–459. https://doi.org/10.1016/j.sbspro.2014.07.224

[28] Basu, S., Saha, P. (2017). Regression models of highway traffic crashes: A review recent research and future research needs. 10th International Scientific Conference Transbaltica 2017: Transportation Science and Technology, 187: 59-66. https://dx.doi.org/10.1016/j.proeng.2017.04.350

[29] Nilsson, P., Nilsson, S. (2015). Application of poisson regression on traffic safety. Master Thesis of SCI School of Engineering Sciences, KTH Royal Institute of Technology, Stockholm, Sweden.

[30] Zhang, Y., Zou, Y., Wu, L., Tang, J., Abid, M.M. (2020). Exploring the application of the linear Poisson autoregressive model for analyzing the dynamic impact of traffic laws on fatal traffic accident frequency. Journal of Advanced Transportation, (Article ID 8854068): 1–9. https://dx.doi.org/10.1155/2020/8854068

[31] Stam, D., Cignini, F., Domenichini, L., Alessandrini, A. (2018). ARTS for last-mile transport designing and integrating into cities. In Implementing Automated Road Transport Systems in Urban Settings, 17-80. https://dx.doi.org/10.1016/b978-0-12-812993-7.00002-4

[32] Ginta, A.M., Juniardi, F., Yosomulyono, S. (1997). Evaluasi geometrik jalan pada ruas jalan sungai raya kepulauan, kabupaten bengkayang – sambas, kalimantan barat. JeLAST: Jurnal PWK, Laut, Sipil, Tambang, 6(3): 1–8. http://dx.doi.org/10.26418/jelast.v6i3.36711

[33] Vathony, A., Purnama, D.H. (2000). Analisis Operasional Jalan Luar Kota pada Ruas jalan Magelang (Tempel) sampai dengan Tahun 2009. Undergraduate Essay UII.

[34] Fambella, B.C., Sulaksitaningrum, R., Arifin, M.Z., Bowoputro, H. (2014). Evaluasi dan Perencanaan Geometrik Jaringan Jalan di dalam Universitas Brawijaya, Malang. Jurnal Mahasiswa Jurusan Teknik Sipil, 1(3): 1146-1154.

[35] Hidayah, P.I. (2013). Evaluasi Geometrik Jalan pada Jenis Tikungan Spiral-Circle-Spiral dan Spiral-Spiral (Studi Kasus Jalan Tembus Tawangmangu Sta 2+223.92 – Sta 3+391.88)". Jurnal Proyek Akhir.

[36] Ramdhani, F., Hermawan, H. (2016). (Indonesian language): Analisis Peningkatan Jalan pada Ruas Jalan Luragung-Cidahu. Jurnal Konstruksi, 5(5): 497-506.

[37] Prabandini, F., Herijanto, W. (2016). Geometric and Pavement Design on Panggul – Sobo Village Road Section, Project of the Southern Java Ring Road, East Java Province. Undergraduate Essay ITS, Surabaya.

[38] Goeritno, A., Nurmansyah, D., Maswan. (2020). Safety instrumented systems to investigate the system of instrumentation and process control on the steam purification system. International Journal of Safety and Security Engineering, 10(5): 609-616. https://doi.org/10.18280/ijsse.100504

[39] Goeritno, A., Nugraha, I., Rasiman, S., Johan, A. (2020). Injection current into the power transformer as an internal fault phenomena for measuring the differential relay performance. Instrumentation Mesure Métrologie, 19(6): 443-451. https://doi.org/10.18280/i2m.190605

[40] Goeritno, A., Setyawibawa, I., Suhartono, D. (2021). Designing a microcontroller-based half-duplex interface device drove by the touch-tone signal. J. INFOTEL, 13(4): 205-215. https://dx.doi.org/10.20895/infotel.v13i4.712

[41] Goeritno, A., Setyawibawa, I. (2021). An electronic device reviewed by diagnosing on the module embodiment. International Journal of Electronics and Communications System, 1(2): 41-55.

NOMENCLATURE

EWS	Early Warning System
DAS	Driving Assistance System
VNs	Vehicular Networks
TTC	Time To Collision
Sta.	Station
m	meter
m/s	meter per second
km/h	kilometers per hour
SL	Straight Line
C	Circle
SC	Spiral Circle
PCE/h	Passengers Car Equivalent per hour
2/2 UD	Two ways/Two Lines, Undivided
UI	User Interface
AEK	Accident Equivalence Figures