ISSN: 2581-1274

Geometric Evaluation of Road Construction on the Ir. Sutami PJR Climb Bandar Lampung Using Topographic Measurements

Meraty Ramadhini [a,1,*], Akbar Wahyu Nugraha [a,2], Dandy Ardian Dani Saputro [a,3], Safridatul 'Audah [b,4]

[a] *Department of Geomatics Engineering, Institute of Technology Sumatera, Terusan Ryacudu, Lampung Selatan 35365, Indonesia*
[b] *Department Civil Engineering, Riau University, Kampus Bina Widya Km 12,5 Simpang Baru Pekanbaru 28293, Indonesia*
[1] *meraty.ramadhini@gt.itera.ac.id*;* [2] *akbar.nugraha@gt.itera.ac.id;* [3] *dandy.119230039@student.itera.ac.id;* [4] *Safridatul@lecturer.unri.ac.id*

ARTICLE INFO

Article history:
Accepted

Keywords:
PJR Bandar Lampung
Road Geometric
Horizontal Alignment
Vertical Alignment

ABSTRACT

In general, steep inclines are made winding for the reason that they reduce the energy required to reach the same height. The slope of the incline will be gentler with curves so it is easier to climb, because the car does not have enough power to climb steep slopes so the road is made winding. Based on accident data from the KNKT, the highest number of accidents that occurred on the PJR Bandar Lampung ramp was 21 incidents in a year. Geometric road on an incline. The winding and narrow condition of PJR Bandar Lampung makes it difficult for vehicles to pass this section of road. The aim of this research is to carry out geometric analysis and evaluation of roads on the PJR Bandar Lampung incline based on Road Geometric Design Guidelines Number 13/P/BM/2021 using topographic measurements. The results of the geometric evaluation of the road were suitable for corner 4 with a superelevation below 6% and with a minimum radius from a speed of 20 km/h to 50 km/h, while the results were not suitable for the average ideal lane width of 3 m. maximum superelevation is 10.01%, maximum slope is 9.81% and critical slope length is 9.33%. So the road geometry does not comply with Road Geometric Design Guidelines Number 13/P/BM/2021.

I. Introduction

Geometric road planning is part of road planning which focuses on planning the physical form so that it can fulfill the basic function of the road, namely providing optimum service to traffic flow and maximizing the ratio of use to implementation costs, so as to provide a sense of security and comfort to road users. A road plan is expected to fulfill basic functions the road is to provide optimal service to the traffic flow that passes through it.

In general, steep climbs are made winding for the reason that they reduce the energy required to reach the same height. The slope of the incline will be gentler with the curves making it easier to climb, because the car does not have enough energy to climb steep slopes so that the road is made winding [1]. However, there are some climbs that have geometric construction one example is the PJR ramp in Way Laga Village, Panjang District, Bandar Lampung City. Road accidents contribute the largest percentage of losses and loss of life in accidents [2]. Accidents can be caused by several factors including vehicle roadworthiness, human negligence, environmental conditions, and also road geometric conditions [3]. The level of traffic accidents is greatly influenced by human factors, one of which is the speed factor. Vehicle speed is very influential in road accidents highway, especially in corner areas. The number of accidents on curves is around 1.5 to 4 times more than accidents on straight roads. Deaths and damage due to road accidents at curves are around 25% -30%. Sharp bends are locations that are very prone to accidents. Standard horizontal alignment geometry allows sharp turns only for roads with certain functions and low speeds [3].

Road geometric planning that is not in accordance with local regional conditions is the main factor for the author evaluate the geometric condition of the road. This road section is a combination of horizontal curves and vertical road curves, this road section is road sections that are prone to accidents. When a car wants to enter an incline, it is very difficult to control the speed of the vehicle, so the vehicle will lose speed when going uphill. Vehicles are required to use low gear to be able to pass the incline of the road, this can result in the vehicle losing half of its speed when starting to climb. This road section is a road section that is at high risk of accidents. Evaluation of several aspects of road planning needs to be carried out to determine the overall performance of a road in order to produce safer infrastructure, increase the efficiency of traffic flow services and maximize the usage rate ratio. Geometric evaluation of road construction is carried out by measurements topography, the results of this measurement are to determine the horizontal and vertical geometric shape of the next PJR incline will be analyzed based on Road Geometric Design Guidelines Number 13/P/BM/2021.

II. Research Method

The preparation stage is the initial stage in carrying out research. The preparation stage aims to support the smooth process of subsequent activities. This preparation stage consists of several parts, namely determining the research location, preparing equipment and preparing research materials.

A. Research Location

The location of this research is in Way Laga Village, Panjang District, Bandar Lampung City, Lampung 35245, which is more precisely called the PJR climb which stands for Puncak Jeruk Hill.

Fig. 1. Research Location

B. Stages in Reseacrh

- In the initial stage, data acquisition planning is carried out, such as the time for data collection, the planned location of control points, the planned length of the road to be measured, the distance between STAs, and the tools used.
- The data acquisition stage was carried out directly in the field by measuring the control frame, longitudinal sections, cross sections and detailed situations.
- Horizontal control frame measurements were carried out using a GNSS receiver with a net mode differential static method. Measurements were carried out in 2 sessions with an observation duration of 2 hours in each session. The baseline distance between INACORS ITERA and the control framework is approximately 8 Km.
- Cross-sectional and longitudinal cross-sectional measurements were carried out on part of the PJR Bandar Lampung road which is the research area. This measurement was carried out to see and determine the geometric shape of the road in PJR Bandar Lampung.
- Measurement of the longitudinal cross section of the road is carried out by measuring the middle of the road or center line of the road. The data collection distance from each point is 5 meters for bends and 10 meters for straight roads.
- Measuring the cross section of the road is carried out by following the point of the cross section. The points taken at each cross section are 5 points, namely left side (LS), left (L), center line (CL), right (R), and right side (RS).
- Detailed measurements of this situation were carried out to describe the topographic conditions around the road. The details of the situation taken were measurements 1 meter from the road

body. This measurement is intended as supporting data to see the extent of the elevation difference between the road body and the existing road land.

- The geometric depiction of the road carried out is the depiction of the transverse profile of the road, the depiction of the longitudinal profile of the road, and the existing condition of the road. Longitudinal profile drawing is carried out on the center line of the road using data on the horizontal distance between points on the center line of the road and the elevation of each point. Transverse profile drawing is carried out with each STA point of the cross section. From this depiction you can see the width of the road and the superelevation of the road. The existing condition of the road is a depiction from above the road. There are longitudinal and cross-sectional shapes of the road.
- Road geometry is analyzed to determine the components of road geometry, namely horizontal alignment and vertical alignment. The components of the horizontal alignment that will be determined are lane width, superelevation and minimum radius. The components of a vertical alignment are the maximum slope and the critical slope length. These components will be compared with the Road Geometric Design Guidelines Number 13/P/BM/2021, so that an evaluation of the road geometry on the PJR Bandar Lampung incline can be carried out. This evaluation will determine the suitability of the road geometry on the PJR Bandar Lampung incline.
- Superelevation calculations were carried out at the curve on the PJR Bandar Lampung Hill. The total bends this climb has are 4 bends. The calculation is carried out from the first bend, namely at STA 0+020 – 0+075, then at the second bend, namely at STA 0+185 – 0+220, at the third bend, namely at STA 0+305 -0+335, and at the fourth bend, namely at STA 0+400 – 0+480 using the equation [5]:

$$e = \frac{\Delta_H}{d} \times 100\% \quad (1)$$

The notation in equation (1) is as follows:

e : superelevation

Δ_H : height difference across the road

d : transverse distance

- The calculation of the maximum slope of the road in this study is calculated using the following equation [5]:

$$\Delta = \frac{\Delta_H}{d} \times 100\% \quad (2)$$

The notation in equation (2) is as follows:

Δ : maximum slope

Δ_H : height difference along the road

d : longitudinal distance

The maximum slope calculation is carried out at each corner. The calculation is carried out on four corners.

- The calculation of the critical slope length in this study is calculated using the equation [5]:

$$g = \frac{\Delta_{\text{elevasi}}}{total\ jarak}\, x\ 100 \quad (3)$$

This calculation is carried out using the initial elevation and final elevation of a slope with the aim of seeing the overall percentage of the road terrain.

III. Results and Discussion

A. Benchmark (BM) Measurement Results

Benchmark coordinates produced through GNSS measurements using the net mode differential static method are used as a reference point in taking detailed point measurements in the field. In this study, 4 reference points were measured with 2 observation sessions and each session had a measurement duration of 2 hours. From the results of the GNSS measurements and processing that have been carried out, the results presented in Table 1 are obtained as follows.

Table 1. Benchmark (BM) Coordinate Results

No	N	E	U	Information
1	9398487.679	534587.207	76.128	Point 1
2	9398556.228	534680.491	85.956	Point 2
3	9398497.937	534791.597	95.657	Point 3
4	9398555.452	534445.379	64.181	Point 4
5	9407409.768	534588.124	114.995	INACORS

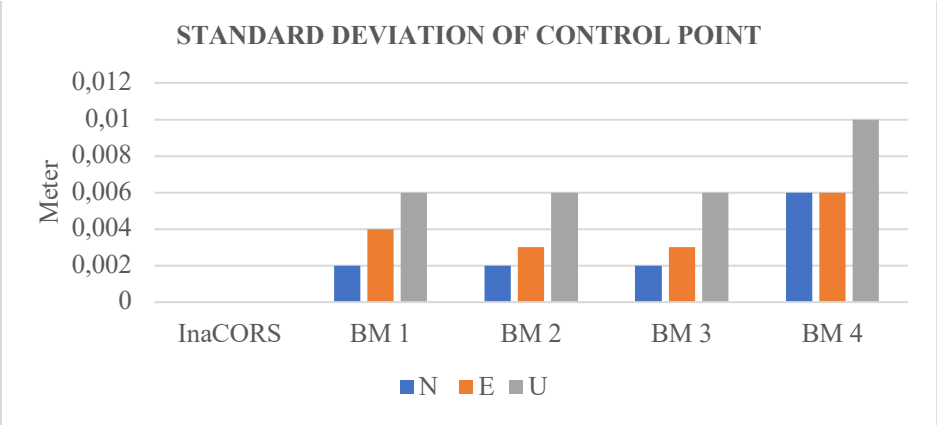

Fig. 2. Control Point Accuracy Graph

The accuracy seen from the northing standard deviation, easting standard deviation and up standard deviation values shows that overall the coordinate accuracy has a very good value.

B. Topographic Measurement Results

The total coordinate points produced in this measurement are 78 STAs with a total of 78 coordinate points per line and a total of 415 coordinate points with a distance between STAs of 10 meters for straight roads and 5 meters for bends on the slope.

Determining the distance of each STA and determining the distribution of detailed points taken was carried out in order to obtain better data with the aim of obtaining significant changes in the topography of the observation area. The height value at each STA on the incline always increases. This defines that the climb is a long and steep climb category because it does not have the slightest drop in elevation on the incline.

C. Horizontal Alignment Evaluation Results

Based on the results of research conducted on the Ir. Sutami PJR Bandar Lampung which refers to the Road Geometric Design Guidelines Number 13/P/BM/2021 ramp Ir. Sutami PJR Bandar Lampung has a 2 lane 2 direction undivided road type (2/2 TT) and based on its function is classified as an arterial road. The road class based on its use is included in the class 1 road classification where the vehicle width is ≤ 2.5 m, length ≤ 18 m, height ≤ 4.2 m and the heaviest axle load is 10 tons.

D. Ideal Lane Width

The smallest ideal lane width that has been determined is 2.75 m for low speed, 3.50 m for medium speed, and 3.60 m for high speed. From the research that has been carried out, this incline is classified as a medium road (JSD), a public road that serves medium distance traffic, with at least two lanes in both directions with a standard lane width of at least 7 m. From the ideal lane width calculations that have been carried out, the slope of Ir. Sutami PJR Bandar Lampung has an average lane width of 3 m and a lane width of 6 m. If this is related to the applicable regulations, these lanes do not comply with the applicable regulations.

E. Road Terrain Classification Results

Road terrain classification is determined to identify and separate the types of terrain or surfaces that exist on a particular road or area. The following are the results of road terrain classification based on existing conditions.

Table 2. Road Terrain Classification

STA	Height Difference (m)	Distance (m)	Percentage (%)
0+000 - 0+050	4.423	50	8.85
0+050 - 0+100	4.573	50	9.15
0+100 - 0+150	4.133	50	8.27
0+150 - 0+200	3.559	50	7.12
0+200 - 0+250	4.409	50	8.82
0+250 - 0+300	4.570	50	9.14
0+300 - 0+350	3.768	50	7.54
0+350 - 0+400	3.942	50	7.88

If it is related to the 1997 Geometric Road Planning Procedures regulations, the slope of Ir. Sutami PJR Bandar Lampung is classified as hilly terrain with a percentage of 3% - 25%. With the emergence of new regulations, namely Road Geometric Design Guidelines Number 13/P/BM/2021, the PJR Bandar Lampung incline is included in the classification of inclines on flat terrain with a calculated result of <10%.

F. Maximum Superelevation results

The superelevation set for flat terrain is 8% for intercity roads, urban roads and freeways according to Road Geometric Design Guidelines Number 13/P/BM/2021.

Table 3. Superelevation Value

Bend	STA	Different Height (m)	Lane Width (m)	Superelevation (%)
1	0+020	0.355	6.713	5.29%
	0+025	0.403	6.880	5.86%
	0+030	0.405	7.007	5.78%
	0+035	0.863	9.036	9.55%
	0+040	0.414	6.413	6.46%
	0+045	0.398	6.232	6.39%
	0+050	0.347	6.315	5.50%
	0+055	0.299	6.567	4.55%
	0+060	0.257	7.063	3.64%
	0+065	0.104	7.095	1.47%
	0+070	0.035	7.034	0.50%
	0+075	0.118	6.994	1.69%
2	0+185	0.418	7.048	5.93%
	0+190	0.399	7.022	5.68%

Bend	STA	Different Height (m)	Lane Width (m)	Superelevation (%)
	0+195	0.495	7.056	7.02%
	0+200	0.43	7.019	6.13%
	0+205	0.464	7.134	6.50%
	0+210	0.416	7.194	5.78%
	0+215	0.393	7.152	5.49%
	0+220	0.357	7.160	4.99%
	0+225	0.269	7.156	3.76%
	0+305	0.026	7.130	0.36%
	0+310	0.652	7.157	9.11%
	0+315	0.577	7.056	8.18%
3	0+320	0.581	7.192	8.08%
	0+325	0.711	7.100	10.01%
	0+330	0.286	6.744	4.24%
	0+335	0.395	6.955	5.68%
	0+400	0.118	6.956	1.70%
	0+405	0.07	7.089	0.99%
	0+410	0.069	7.061	0.98%
	0+415	0.109	7.057	1.54%
	0+420	0.131	6.960	1.88%
	0+425	0.212	6.859	3.09%
	0+430	0.266	6.924	3.84%
	0+435	0.346	6.923	5.00%
4	0+440	0.353	6.953	5.08%
	0+445	0.324	6.873	4.71%
	0+450	0.278	6.897	4.03%
	0+455	0.224	6.817	3.29%
	0+460	0.177	6.836	2.59%
	0+465	0.168	6.955	2.42%
	0+470	0.068	6.977	0.97%
	0+475	0.072	6.892	1.04%
	0+480	0.053	6.819	0.78%

The result of some inappropriate bend superelevation. At STA 0+320 the resulting superelevation is 8.08%, at STA 0+315 the resulting superelevation is 8.18%, at STA 0+310 the resulting superelevation is 9.11%, at STA 0+035 the resulting superelevation is 9.55 % and the highest superelevation was produced at STA 0+325 with a superelevation of 10.01%. The superelevation results are depicted in Figure 3 below.

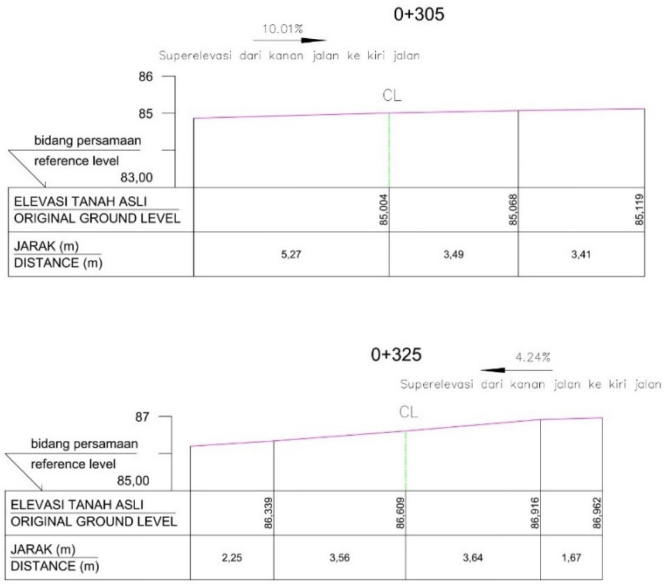

Fig 3. Largest and Smallest Superelevation

Sample cross-sectional profile of the road section. The smallest superelevation was obtained at STA 0+325 with a value of 4.24% and the largest superelevation was obtained at STA 0+305 with a value of 10.01%. Superelevation refers to the slope of the road track at curves to increase the safety and comfort of road users, especially at curves.

G. Minimum Radius

The bend on the PJR Bandar Lampung incline is included in the full circle bend category because it has a bend that only consists of part of a circle. The minimum radius at a bend can be determined based on two aspects, namely design speed and maximum superelevation. Design speed (VD) based on road class, road type and road type is 15 - 60 km/hour. Apart from the design speed, the maximum superevelation value also influences the determination of the minimum radius. This maximum superelevation value is divided into 3 namely 4%, 6% and 8%, which can be seen in tables 4 to 7 below.

Table 4. PJR 1 Climb Radius

V_D (Km/Hour)	Superelevation (e_{max})			Existing Radius (m)	Information
	4%	6%	8%		
	Rmin (m)	Rmin (m)	Rmin (m)		
20	15	15	10	39.271	Suitable
30	35	30	30	39.271	Suitable
40	60	55	50	39.271	Not Suitable
50	100	90	80	39.271	Not Suitable
60	150	135	125	39.271	Not Suitable

Table 5. PJR 2 Climb Radius

V_D (Km/Hour)	Superelevation (e_{max})			Existing Radius (m)	Information
	4%	6%	8%		
	Rmin (m)	Rmin (m)	Rmin (m)		
20	15	15	10	43.329	Suitable

V_D (Km/Hour)	Superelevation (e_{max}) 4% Rmin (m)	6% Rmin (m)	8% Rmin (m)	Existing Radius (m)	Information
30	35	30	30	43.329	Suitable
40	60	55	50	43.329	Not Suitable
50	100	90	80	43.329	Not Suitable
60	150	135	125	39.271	Not Suitable

Table 6. PJR 3 Climb Radius

V_D (Km/Hour)	Superelevation (e_{max}) 4% Rmin (m)	6% Rmin (m)	8% Rmin (m)	Existing Radius (m)	Information
20	15	15	10	39.271	Suitable
30	35	30	30	39.271	Suitable
40	60	55	50	39.271	Not Suitable
50	100	90	80	39.271	Not Suitable
60	150	135	125	39.271	Not Suitable

Table 7. PJR 4 Climb Radius

V_D (Km/Hour)	Superelevation (e_{max}) 4% Rmin (m)	6% Rmin (m)	8% Rmin (m)	Existing Radius (m)	Information
20	15	15	10	132.554	Suitable
30	35	30	30	132.554	Suitable
40	60	55	50	132.554	Not Suitable
50	100	90	80	132.554	Not Suitable
60	150	135	125	132.554	Not Suitable

The corner radius value on the PJR Bandar Lampung ramp obtained from existing road data is 39.271 m for the first corner, 43.329 m for the second corner, 39.271 m for the third corner and 132.554 m for the fourth corner. The minimum radius value on the PJR Bandar Lampung incline is included in the standard road geometric guidelines at a design speed of 20 to 30 km/h at corner 1 to corner 3 while at corner four at a design speed of 20 km/h to 50 km / hour is in accordance with Road Geometric Design Guidelines Number 13/P/BM/2021, at the fourth corner at a design speed of 60 km/hour with a superelevation of 8% it is in accordance with Road Geometric Design Guidelines Number 13/P/BM/2021, while at the planned speed of 60 km/h to 120 km/h the minimum radius on the PJR Bandar Lampung incline does not comply with the superelevation of 4%, 6% and 8%. This shows that on the PJR Bandar Lampung ramp it is necessary to equalize the minimum radius in accordance with the Road Geometric Design Guidelines Number 13/P/BM/2021.

H. Vertical Alignment Evaluation Results

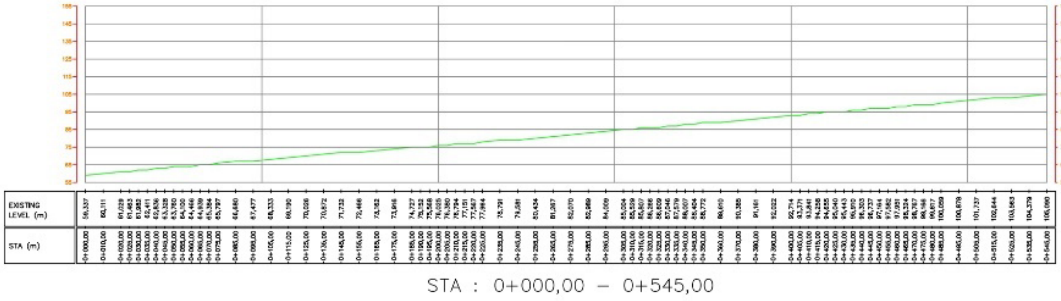

Fig 4. Long Section Processing Results (Longitudinal Cuts)

The lowest height difference was found at STA 0 namely 1.337 m and the highest height difference was found at STA 83 namely 47.090 m. The total vertical distance measured was 550.964 m, while the total horizontal distance measured was 549.064 m.

I. Maximum Ramp

Based on research that has been carried out on the Ir. Sutami PJR Bandar Lampung, the incline is classified as flat terrain and based on the Road Infrastructure Provider Specifications (SPPJ) it is classified as JSD or Road with moderate traffic. The maximum slope allowed based on Road Geometric Design Guidelines Number 13/P/BM/2021 for this classification is 6%.

Table 8. Maximum Slope Value

Horizontal Length (m)	Height Difference (m)	Slope	Information
58.659	4.768	8%	Not Suitable
37.942	3.237	8.53%	Not Suitable
48.000	3.768	7.85%	Not Suitable
62.081	6.088	9.81%	Not Suitable

The road alignment has 4 vertical curves and it can be seen that the maximum slope is on the Ir slope. Sutami PJR Bandar Lampung was 8% on the first curve, 8.53% on the second curve, 7.85% on the third curve and 9.81% on the fourth curve. From the calculations that have been carried out, it can be concluded that the maximum slope of the incline is not in accordance with the Road Geometric Design Guidelines Number 13/P/BM/2021.

J. Length of Critical Slope

The critical slope length determined by Road Geometric Design Guidelines Number 13/P/BM/2021 at a distance of 549.064 m is 4%. In the calculation above, the results obtained were 8.33% of the critical slope length which was calculated using direct measurement data in the field. This is completely inconsistent with the established rules. This of course creates difficulties and dangers in climbing hills, especially for heavy vehicles or vehicles with large loads.

IV. Conclusion

Based on the results and discussion of the process of carrying out this research, the following conclusions were obtained:

1. The PJR Bandar Lampung climb has road specifications that do not comply with the Road Geometric Design Guidelines Number 13/P/BM/2021 as proven by the results of horizontal alignment and vertical alignment analysis carried out based on direct measurements in the field.
2. It was found that an inappropriate lane width was 3 m, inappropriate superelevation in several STAs with the highest result being 10.01% where the maximum superelevation allowed was 8%, and an inappropriate maximum slope length and critical slope length of 8 % on the first bend,

8.53% on the second bend, 7.53% on the third bend and 9.81% on the last bend for maximum slope and for the critical slope length of 8.33%.

References

[1] Chasanah, K. P. (2018). Evaluasi Alinyemen Vertikal dan Horizontal Studi Kasus di Depan Gedung Perpustakaan Kampus Dramaga IPB. . Jurnal Teknik Sipil Dan Lingkungan.

[2] Sumarsono, A., Pramesti, F. P., & Sarwono, D. (2010). Model Kecelakaan Lalulintas Di Tikungan Karena Pengaruh Konsistensi Alinyemen Horizontal dalam Desain Geometrik Jalan Raya. Media Teknik Sipil, X(Juli), 85–92.

[3] Manggala, R., J., J. A., Purwanto, D., & Indriastuti, A. K. (2016). Studi kasus faktor penyebab kecelakaan lalu lintas pada tikungan tajam. Jurnal Karya Teknik Sipil, 4(4), 462–470. https://ejournal3.undip.ac.id/index.php/jkts/article/view/10575.

[4] Direktorat Jenderal Bina Marga. (2021). Surat Edaran Direktur Jendral Bina Marga Nomor 20/SE/Db/2021. Jakarta: Direktorat Jendral Bina Marga.

[5] Kementerian PUPR Dirjen. Bina Marga. (2021). Pedoman Desain Geometrik Jalan No. 13/P/BM/2021.

[6] Saputro, Dandy, A. D. (2023). Evaluasi Geometrik Konstruksi Jalan Pada Tanjakan Ir Sutami Pjr Bandar Lampung Menggunakan Pengukuran Topografi. Tugas Akhir Teknik Geomatika. Institut Teknologi Sumatera.