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Evaluasi Alinyemen Horizontal di Jalan Bogor Inner Ring Road dengan Building Information Modelling (BIM)

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ABSTRACT

Safety and comfort are crucial in road design. Thorough evaluations are necessary to ensure adherence to standards. The BIM system expedites this process by identifying non-compliant elements. The evaluation results include PVI coordinates and bend data, providing insights into vertical and curvature aspects. BIM facilitates the efficient identification of areas requiring attention. This ensures accurate road projects, minimizing safety risks and ensuring comfort. Prioritizing safety and comfort in road design requires rigorous evaluation and BIM implementation to identify non-compliant elements efficiently. PVI coordinates and bend data provide valuable insights for assessing vertical and curvature aspects. BIM contributes to safer and more comfortable road infrastructure.

1. Introduction

The state is a territory where people with common interests gather, and one of a country's interests is its citizens' welfare. To ensure the welfare of citizens, various measures are taken, including the utilization of human resources and the maximization of natural resources. Additionally, the country's human and natural resources must be interconnected through communication. Communication is important in improving the welfare of a country. In line with this, the highway was constructed to provide comfort and safety for road users while facilitating the smooth movement of vehicles (Salsabila, Irfan Rifai, & Isradi, 2023).

As the largest archipelago country globally, Indonesia has abundant human and natural resources scattered across its islands. Utilizing these resources has the potential to boost the Indonesian economy rapidly. Effective communication is crucial to maximizing their potential fully; one aspect is traffic management. Establishing land transportation networks, including toll roads, can expedite the distribution of goods and services. However, it is essential to prioritize the comfort, safety, and smoothness of road users' experiences. As crucial infrastructure, roads serve as connectors between different areas, playing a vital role in the community service system (Ulchurriyyah, Rifai, & Taufik, 2023). They facilitate the transportation of people, goods, and services, ensuring efficient connectivity within and between regions.

Bogor is one of Indonesia's cities with the largest population, namely 5,427,068 people, based on the population census in 2020. Bogor is also one of the routes commonly used to go to other cities. This causes the level of congestion to be high. Therefore, in the Bogor area, Jalan Bogor Inner Ring Road is made, which will be connected directly to the toll road to reduce the level of congestion without compromising the safety and comfort of road users.

Suitable, safe, and smooth roads in Indonesia can be constructed based on the DGH 2021 reference, which is widely used. To expedite the evaluation process and adhere to the Highways reference, implementing the BIM (Building et al.) system is recommended. Several software tools, such as

Autodesk Civil 3D®, Autodesk Infraworks, Global Mapper, and 3DS Max, can be utilized. In particular, using AutoCAD Civil 3D® makes it easier for road planners to design geometrically accurate roads (Salsabila, Rifai, & Taufik, 2023). This software provides efficient tools and features that assist in the planning and layout road geometries, ensuring precise and well-designed road alignments. The development of technology today is increasing in earlier times (Ulchurriyyah, Rifai, & Taufik, 2023).

The purpose of this paper is so that readers can keep up with the times using BIM technology and can make road geometries that are safe, comfortable, and smooth more quickly. We hope to keep up with all the developments of the times, but we also need to refine these developments to make changes for the better, not the other way around.

2. Literature Review

Road Geometry

Road geometry is part of road planning which has the primary function of providing full service to traffic flow. Highway infrastructure plays an essential role in ensuring the proper functioning of national transport (Maulana, Rifai, & Isradi, 2023). Geometric road planning is essential to develop good road infrastructure (Farid, Rifai, & Taufik, 2023). By carefully designing road geometry, engineers aim to optimize road networks' efficiency, safety, and capacity to accommodate the expected traffic volume.

Efficient traffic flow is a fundamental goal of road planning, as it ensures that vehicles can move smoothly and without unnecessary delays. The speed of vehicles on certain roads indicates the road's flow (Immanuel, Rifai, & Prasetijo, 2022). When roads are designed with proper geometry, including factors like lane widths, curves, intersections, and signage, it significantly improves the ability of vehicles to navigate the road network effectively. This means less congestion, reduced travel times, and increased road safety. To overcome this, road maintenance is carried out continuously with good planning and sufficient maintenance, as well as road-type maintenance can be a solution (Muatan, Rifai, & Handayani, 2023).

Road Alignment is a projection of an arc on the geometric road (Nugroho, Rifai, & Akhir, 2023). Road geometric is divided into horizontal alignment and vertical alignment, which integrate with each other according to standards to achieve the goal itself. Each geometry is designed according to standards so that the vertical and horizontal alignments do not endanger road users. These standards are listed in the software that will be used.

Horizontal Alignment

Horizontal alignment refers to the layout of a road in the horizontal plane, precisely the curvature or bends along its path. The main task of the horizontal paragraph design is to determine the tangent cut point, circular curve, and transition curve(Pangesti, Rifai, & Prasetijo, 2023). It determines the smoothness and efficiency of vehicle movement, ensuring safe navigation through curves and bends. When designing the horizontal alignment of a road, engineers consider factors such as cost, compliance with standards, and the topography of the construction site, including the contours of the land.

The development of horizontal alignment theory to support effective and safe road planning is growing, one of which is using trajectory speed (Joice, Rifai, & Taufik, 2023) . The relationship between plan speed and horizontal alignment is significant. Plan speed refers to the speed at which a driver is expected to travel on a particular segment of the road. It depends on factors such as design speed, road curvature, and driver behavior. The horizontal alignment of the road must be designed to match the intended plan speed, ensuring that drivers can comfortably and safely navigate the road. The larger the circular curve/radius, the more comfortable the driver passes through the horizontal alignment (Andito, Rifai, & Akhir, 2023).

In addition to planning the design, efficiency in planning must be considered. Efficiency can be achieved by considering several things, including savings in vehicle operating costs (Assalam, Rifai, & Taufik, 2023). Efficient and cost-effective horizontal alignment design involves several primary considerations, such as the topography where the road is made, design standards that must be implemented on the designed road, bends, and super-elevations that are arranged so that motorists feel comfortable when passing it. The cost of the road is a significant factor in horizontal alignment design (You, Yu, Huang, & Hu, 2022).

Building Information Modelling (BIM)

Building Information Modeling (BIM) is a transformative technology within the Architecture, Engineering, and Construction (AEC) industry that revolutionizes the way development projects are planned, designed, and executed. BIM is basically a digital platform that aims to conceptualize an idea for an activity in a virtual space in the application of modeling. BIM must be able to include all activity information in work that functions to collaborate, predict and make decisions regarding a design, construction, cost budget, and maintenance phase (Cornelis, 2022). With BIM, all relevant information pertaining to a project is simulated and consolidated into a comprehensive 3-dimensional model.

The power of BIM lies in its ability to integrate various software applications, and each specialized in different aspects of the construction process. These software applications work in synergy to create a cohesive system that addresses the limitations of individual software programs. Some of the commonly used software in BIM implementation include Global Mapper®, Autodesk Civil 3D®, Autodesk InfraWorks®, and 3DS Max®.

The leading software used in the design is Autodesk Civil 3D®. One of the well-known software for Building Information Modeling for geometric designing roads is AutoCAD Civil 3D® (Pangesti, Rifai, & Prasetijo, 2023). Autodesk Civil 3D® is powerful software specializing in civil engineering and design. It facilitates the creation of accurate and intelligent 3D models of civil infrastructure, including roads, highways, and drainage systems. Civil 3D® provides powerful tools for designing alignments, profiles, and sections, streamlining the design process, and increasing collaboration among project stakeholders. These devices are generally used to minimize design time and evaluate various situations. Another plus of the AutoCAD Civil 3D® program is that it can perform design updates faster with intelligent 3D model-based applications, which dynamically update design elements as changes are made (Megarestya, Rifai, & Isradi, 2023).

Safety

A road must provide safety, comfort, effectiveness, and efficiency for the travel of people and goods (Rosaria, Rifa, & Prasetijo, 2023). Safety and comfort are paramount when it comes to road design, as they directly impact the experience of road users. To enhance driving comfort and ensure safety, one crucial aspect that needs careful consideration is the design of road bends. The shape of a bend should be aligned with the planned speed on the road being designed.

Designing appropriate bends for the intended speed helps mitigate potential hazards and minimize the risk of accidents. When a bend is not designed to accommodate the design speed, there is a significant danger of accidents occurring. For instance, if a bend is too sharp or lacks proper banking, a vehicle traveling at the designated speed may risk skidding, sliding, or even being thrown off the road.

To address these risks, road designers carefully analyze the anticipated speed profile for a given road and incorporate appropriate measures to ensure that bends are designed accordingly. This involves determining the appropriate radius, super-elevation, and banking of the bend, which allows vehicles to navigate the curve smoothly and safely.

3. Method

Project data is primary data and secondary data. Partial data was obtained from consultants in Detail Engineering Design, and supporting data in contours were obtained from Google. The Bogor Inner Ring Road road project under review is section 1 (wangun –datur), located on the Jl Wangun Sindangsari Village, East Bogor District, Bogor City, 4,075 Km long, which can be seen in Figure 1.

Figure 1 Location

4. Result and Discussion

4.1. Contour

Contours are essential in designing road alignment because we can consider efficient and effective road alignments. Object contour plays a vital role in semantic segmentation and image classification (Gong, et al., 2018). Contour lines are imaginary lines that connect points with the same elevation on the earth's surface. The specified path is effective and efficient, and whether it disturbs housing, forests, or places where a road is made, it will interfere with the function of the land. Contours can be made by conducting a direct survey of the area as a surveyor to get the height at each point, representing the height of the area. Another alternative way is to use Google Earth® data and combine it with DEMNAS data using the Global Mapper® software, as shown in Figure 2.

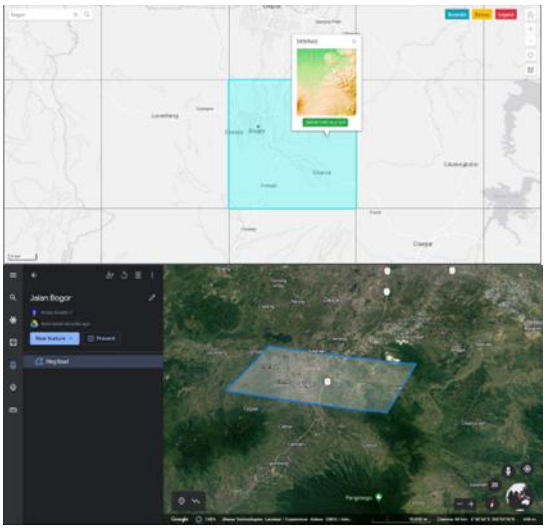
Figure 2 Data Google Earth dan DEMNAS

The Global Mapper® software has one function, which is to combine DEMNAS data and Google Earth® data. The merging process can be seen in Figure 3. The software output can change contours and be used directly in the Autodesk Civil 3D® software. This contour will be the basis and influence the road alignment that will be planned.

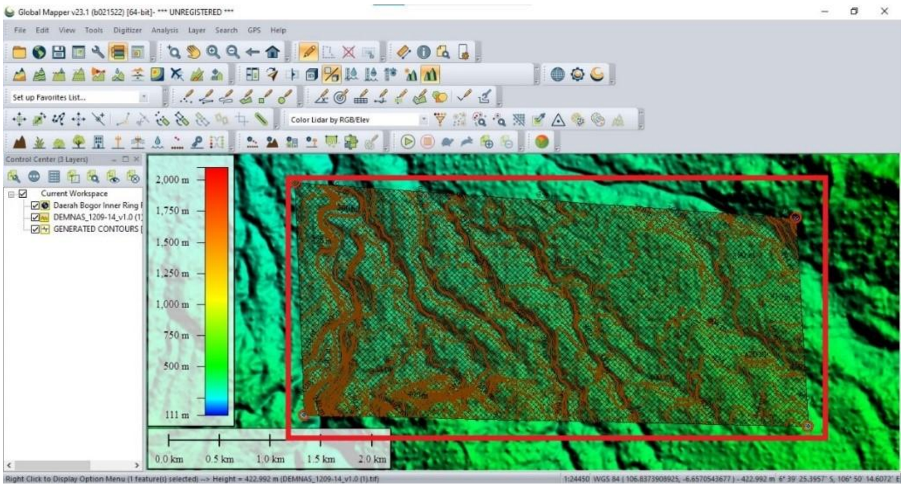

Figure 3 Global Mapper® view

4.2. Autodesk Civil 3D®

The output from the Global Mapper® software is then processed with Autodesk Civil 3D® and inputs the PVI coordinates from the Detail Engineering Design (DED), which is the bend point designed by the DED maker, as shown in the figure. The road alignment formed by the PVI cannot yet be evaluated because the horizontal alignment has not been inputted. The coordinates that have been entered can be seen in Figure 4.

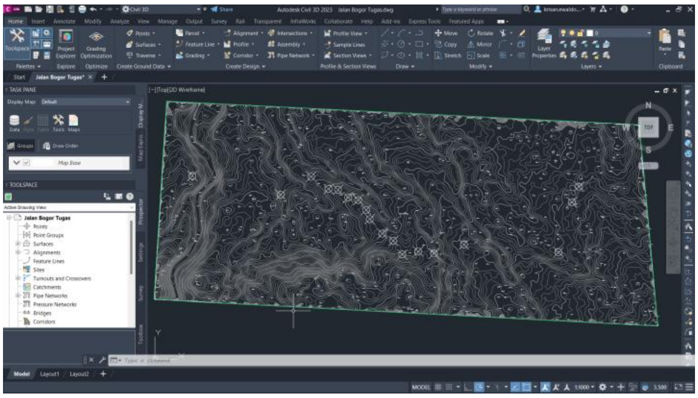

Figure 4 Koordinat PVI

4.3. Horizontally Geometry

All PVI coordinates are connected to a road or horizontal alignment, with each PVI being a bend point adjusted based on the distance between bends. The Autodesk Civil 3D® system will check the bend automatically and display an exclamation mark logo. The logo concludes that the bend section entered does not comply with Autodesk Civil 3D® specifications using the AASHTO 2011 reference. Evaluation of bends sometimes cannot reach the minimum specifications because the distance between bend coordinates is too close, so the PVI coordinates must be changed and readjusted for the bend, as shown in Figure 5.

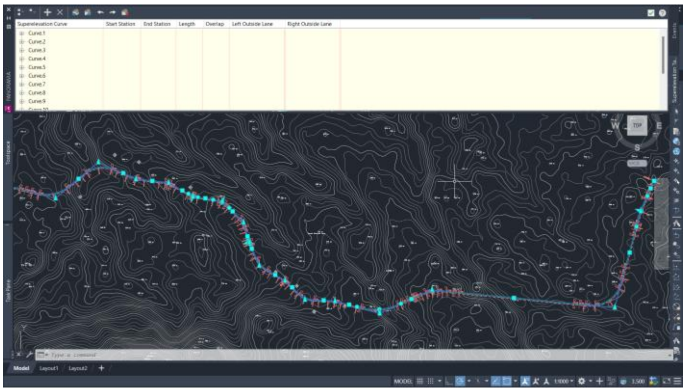

Figure 5 Horizontally Geometry

4.4. Vertical Geometry

In the vertical alignment, the data used follows the DED data. Even though the data displays an exclamation mark logo which means it is not according to specifications, vertical alignment data must be input in order to be modeled, as shown in Figure 6.

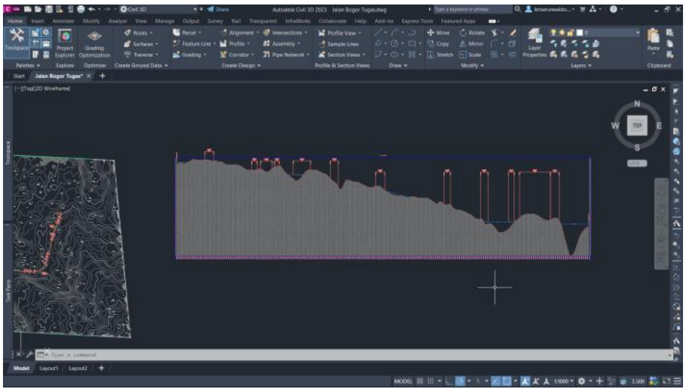

Figure 6 Vertical Geometry

4.5. Cross Section

A cross-section is made to display road animation and make it easier for the reader to understand. The cross-section of the road is a cross-section of the length of the road so that we can find out the layers and road accessories such as sidewalks and others. Adjusting the cross-section of the road can also determine the need for cut and fill to make the road. The cross-section of the road can be seen in Figure 7.

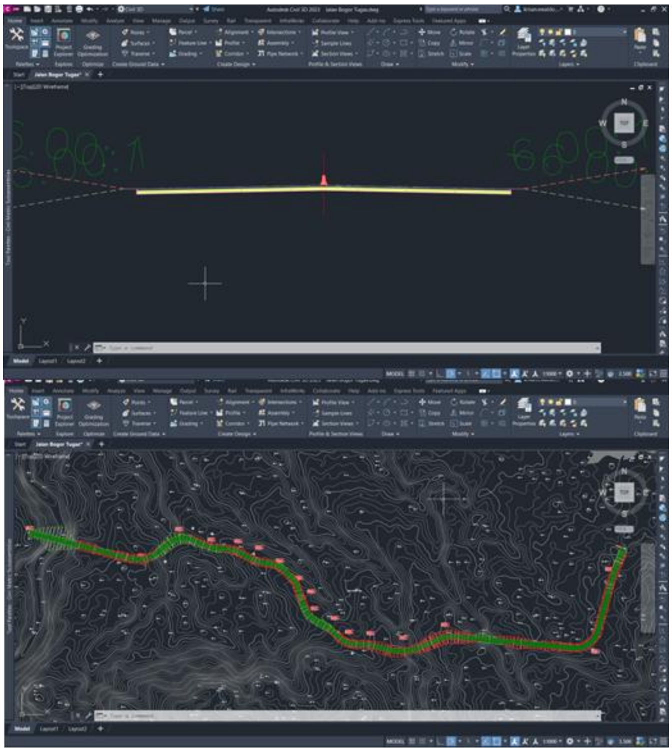

Figure 7 Cross Section view

4.6. 3DS Max

Road planning looks more attractive when applied in an animation. To make the existence of vehicles on the road alignment, you can use the 3DS Max® software. The software uses road alignment on Autodesk Civil 3D®, which will be processed to become a medium for managing vehicle animation. This software can also make the vehicle according to the maximum speed.

4.7. Infrawork

The final part of the application into animation is the Infrawork® software. Autodesk Civil 3D® output, a road alignment, and 3DS Max®, a vehicle animation, are combined into the same Infrawork® software as the 3D version of Google Earth. In infrastructure, buildings can also be added to make the environment better.

4.8. Evaluation

Evaluation is a stage that is carried out to find out whether something being reviewed is following the specifications used. Using Autodesk Civil 3D®, the evaluation process becomes faster and easier. A change in one place immediately updates an entire project, helping your far-reaching projects earlier, brighter, and more accurate (Mandal, Pawade, & Sandel, 2019). The results of inputting data into Autodesk Civil 3D® display a logo symbolizing that the point has a problem or an error that does not comply with the specifications, as shown in Figure 8.

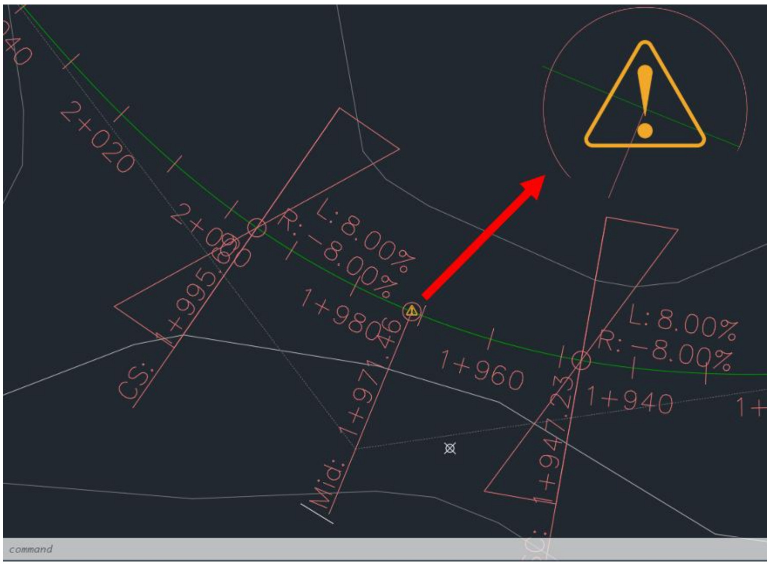

Figure 8 Salah satu Logo Warning terhadap Tikungan

The "warning" indicates a non-compliance with the specifications where a provision is made to ensure the safety and comfort of the rider so that in order to provide security and safety to the rider, the bend data must be changed at a minimum with existing specifications such as the specifications used in Autodesk Civil 3D®. The following changes to the data for each corner that has been evaluated can be seen in Figure 9.

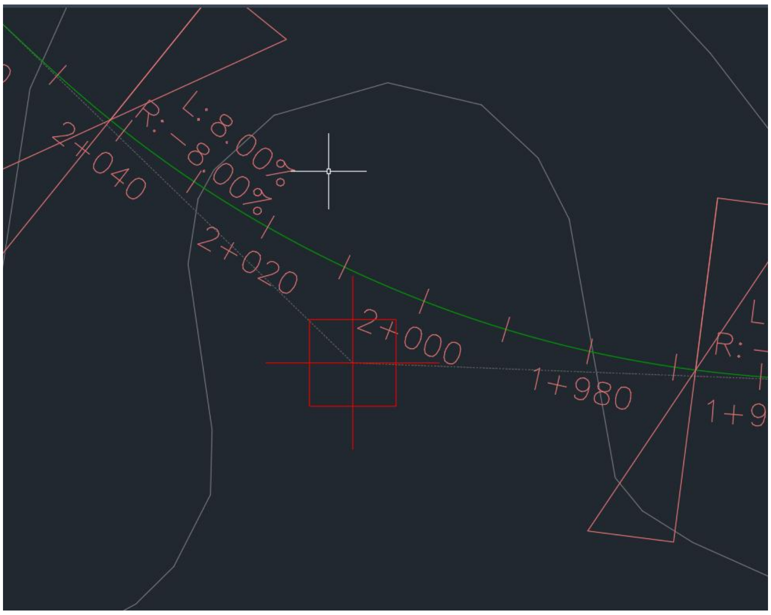

Figure 9 Evaluated bend PVI coordinates and bend size

However, a number of bends have to be rearranged because the coordinates cannot be adjusted according to the bend data with the specifications. The following are the results of changing the coordinates, which can be seen in Tabel 1.

Tabel 1 Tabel hasil evaluasi berdasarkan Spesifikasi AASHTO

Titik	Koordiinat X	Koordiinat Y	Jarak ΔX (m)	Jarak ΔX (m)	Jarak d (m)	Azimuth α	Sudut Tikungan Δ	R	Ls	Lc	L	e	V
START	703501.208	9265074.81						EXISITNG					
			61.286	137.521	150.559	204.02							
PI-1	703439.922	9264937.29					10.444024	950	0	173.168	173.168	en	60
			129.444	8561616	8561616	180.001							
PI-2	703310.478	703321.589					36.983432	130	50	33.913	133.913	0.06	60
			-11.111	-8561175	8561175	180							
PI-3	703321.589	9264496.15					97.187191	150	20	234.435	274.435	0.0593	60
			831.234	-67.873	834.0004	94.668							
PI-4	702490.355	9264564.02					21.4068627	650	0	242.853	242.853	en	60
			263.003	79.099	274.6402	253.261							
PI-5	702227.352	9264484.92					23.9494718	130	50	4.34	104.34	0.06	60
			140.225	-17.741	141.3428	97.2106							
PI-6	702087.127	9264502.66					17.3227208	180	50	4.421	104.421	0.056	60
			139.993	24.967	142.2019	259.888							
PI-7	701947.134	9264477.69					66.2878379	50	50	7.847	107.847	`	30
			79.179	-118.168	142.2427	146.176							
PI-8	701867.955	9264595.86					22.4202575	150	50	8.696	108.696	0.0593	60
			95.908	-64.097	115.355	123.756							
PI-9	701772.047	9264659.96					15.5951149	150	0	40.828	40.828	0.0593	60
			109.863	-127.956	168.6494	139.351							
PI-10	701662.184	9264787.91					18.2411271	150	0	47.755	47.755	0.0593	60
			33.037	-80.121	86.66498	157.592							
PI-11	701629.147	9264868.04					15.9157433	150	30	11.667	71.667	0.0593	60
			69.317	-87.695	111.7822	141.676							
PI-12	701559.83	9264955.73					37.1593825	130	40	44.312	124.312	0.06	60
			88.187	-22.834	91.09522	104.517							
PI-13	701471.643	9264978.56					22.4810404	130	0	51.008	51.008	0.06	60
			89.327	-67.307	111.8461	126.998							
PI-14	701382.316	9265045.87					31.5689377	60	30	3.059	63.059	0.0456	30
			83.602	-7.945	83.97867	95.4287							
PI-15	701298.714	9265053.82					29.739653	100	40	11.905	91.905	0.0594	50
			153.109	-107.88	187.2978	125.168							
PI-16	701145.605	9265161.7					65.8767362	90	50	53.479	153.479	0.0594	50
			268.275	159.343	312.0283	239.292							
PI-17	700877.33	9265002.35					42.8005247	180	50	84.465	184.465	0.056	60
			776.842	-166.429	794.4697	102.092							
FINAL	700100.488	9265168.78											

Titik	X	Y	R	Ls	Lc	L	e	V
START	703501.208	9265074.806	EVALUATION					
PI-1	703439.922	9264937.285	950	0	173.168	173.168	en	60
PI-2	703321.589	9264496.145	135	50	33.913	133.913	0.06	60
PI-3	702485.614	9264577.133	150	24	234.435	274.435	0.0593	60
PI-4	702246.168	9264470.664	300	0	242.853	242.853	en	60
PI-5	702042.69	9264526.368	135	30	4.34	104.34	0.06	60
PI-6	701904.881	9264531.713	135	24	4.421	104.421	0.056	60
PI-7	701813.312	9264620.147	135	24	7.847	107.847	`	30
PI-8	701695.611	9264688.253	150	24	8.696	108.696	0.0593	60
PI-9	701649.364	9264795.84	150	0	40.828	40.828	0.0593	60
PI-10	701624.192	9264885.37	135	24	47.755	47.755	0.0593	60
PI-11	701526.969	9264982.139	135	0	11.667	71.667	0.0593	60
PI-12	701392.313	9265004.237	135	0	44.312	124.312	0.06	60
PI-13	701281.13	9265066.044	135	0	51.008	51.008	0.06	60
PI-14	701132.545	9265083.297	135	30	3.059	63.059	0.0456	30
PI-15	700959.495	9265160.508	135	40	11.905	91.905	0.0594	50
PI-16	700764.831	9264995.855	135	30	53.479	153.479	0.0594	50
PI-17	700877.33	9265002.353	180	50	84.465	184.465	0.056	60
FINAL	700100.488	9265168.782						

Every change that displays a warning symbol can be done quickly because Autodesk Civil 3D® provides minimum specifications for the warning data. We can determine safe bend data by knowing the minimum data according to the specifications used.

6. Conclusion

In the horizontal alignment evaluation process, several conclusions were obtained. Bend data on some PVI does not meet the minimum specifications used in Autodesk Civil 3D®. Changes in data at each corner according to the minimum specifications in Autodesk Civil 3D®. Changes to the PVI coordinates are made if the data at the bend cannot be maximized according to the minimum specifications used in Autodesk Civil 3D®. The evaluation process can be done quickly without looking at the specifications because Autodesk Civil 3D® provides direct minimum specifications for warning bends (below specifications).

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