Geometric Design of the Banjarmasin-Martapura Railway Line

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ABSTRACT

South Kalimantan Province is experiencing population growth and is planned to serve as a supporting area for the National Capital (IKN) of Nusantara. Banjarbaru City, as the provincial capital, is viewed as a potential center for economic growth. The region surrounding Syamsudin Noor Airport is also projected to develop into a hub of strategic activities, which could lead to traffic congestion. Besides Banjarbaru, high passenger demand has also been observed in Banjarmasin City and Martapura. According to the 2030 National Railway Master Plan (RIPNAS), a railway line is planned to connect Banjarmasin, Syamsudin Noor Airport, Banjarbaru, and Martapura. Currently, there is no geometric design available for this railway line, making it necessary to develop a suitable design that aligns with the topographic and other local conditions. This study employs AutoCAD Civil 3D and other supporting software to create the railway design. The proposed railway line spans 42.940 kilometers, with a planned operational speed of 100 km/h, consisting of both at-grade and elevated sections. The design incorporates 15 horizontal curves, with radii of 1660 meters for Full-Circle curves and 560 meters for Spiral-Circle-Spiral curves. The railway is classified as Class I, with a 1435 mm gauge and a double track configuration. The rail type used is 141RE, paired with S-35 concrete sleepers produced by PT. WIKA Beton, and fastened using KA Clip fasteners. The ballast layer has a top layer thickness of 30 cm, while the sub-ballast is 45 cm thick. The estimated construction cost is Rp31,333,291,269,000.00.

INTRODUCTION

South Kalimantan is one of Indonesia's provinces located on the island of Kalimantan, with a population expected to grow. The province is planned to serve as a supporting region and a gateway to the new capital city, Nusantara.

Banjarbaru, the provincial capital, is considered a strategic area with the potential to become an economic growth center in South Kalimantan. Economic growth and development in a region are typically accompanied by increased interaction and travel demand between areas [1]. Currently, Syamsudin Noor International Airport serves as the province's primary air transportation hub. By 2030, the airport is projected to handle approximately 13,285,885 passengers [2], further solidifying its role as a strategic center in South Kalimantan [3]. This growth may lead to traffic congestion due to the increasing flow of passengers and goods. Besides Banjarbaru, cities like Banjarmasin and Martapura also exhibit high passenger demand, with residents often preferring private transportation alternatives [1].

According to the 2030 National Railway Master Plan (RIPNAS), a railway network is planned to connect Banjarmasin and Martapura. The railway system is expected to provide a quality, fast, affordable, reliable, and accessible transportation alternative to meet the growing inter-regional travel demand in South Kalimantan.

Thus, the construction of a railway line in South Kalimantan needs to be planned promptly. One crucial aspect of planning is the geometric design. However, a geometric design for this railway line is currently unavailable. Therefore, this study aims to design a railway line connecting Banjarmasin, Syamsudin Noor Airport, Banjarbaru, and Martapura. The resulting design is expected to serve as a reference for the development of the railway project. Several stages will be undertaken in the railway line planning process, including geometric design, railway construction, and cost estimation.

A. *Problem Statement*

This study aims to address the following questions:

1) How should the geometric design of the railway line between Banjarmasin and Martapura be developed to meet existing technical requirements?
2) What construction design is suitable for the railway line between Banjarmasin and Martapura?

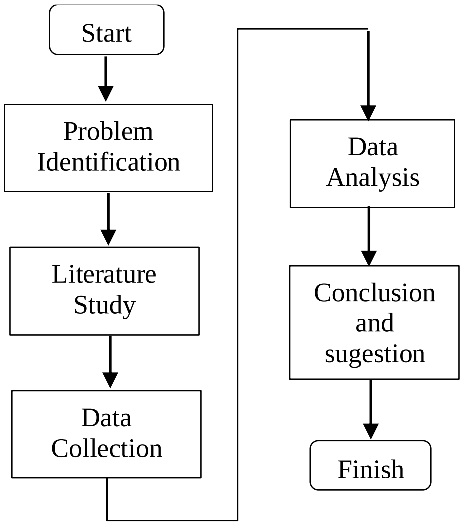

Figure 1 Flow chart.

3) How much will it cost to construct the railway line between Banjarmasin and Martapura?

B. Purpose

The expected objectives of this study include:

1) Designing the geometric railway line between Banjarmasin – Martapura according to the standards of Ministerial Regulation No. 60 of 2012.
2) Designing the construction of the railway line between Banjarmasin and Martapura following the provisions of Ministerial Regulation No. 60 of 2012 and RIPNAS 2030.
3) Estimating the budget required for constructing the railway line between Banjarmasin and Martapura.

C. *Scope and Limitations*

The study's scope is defined as follows:

1) The data used is secondary data.
2) The planned railway line must pass through Syamsudin Noor International Airport and Banjarbaru City.
3) It uses a railroad structure with a width of 1435 mm.
4) Railway rails and wheels are in a non-worn condition, so contact voltage is not discussed.
5) Railway infrastructure, such as stations, dipos, signal houses, etc. are not included in the scope of design.
6) No calculations were made on the construction structure of elevated lines, railway drainage systems, backfill strength, soil improvement methods, and railway tunnel construction.
7) No calculations are made for train travel headways.
8) Does not discuss in detail the planning of the station emplacement layout.

LITERATURE REVIEW

A. Railway Network Plan for Kalimantan Island

The railway network plan for Kalimantan Island is outlined in RIPNAS 2030 [4]. This master plan serves as a guideline for railway development in Indonesia. According to RIPNAS 2030, the development of railway networks in South Kalimantan aims to facilitate freight movement and stimulate regional growth, particularly in the southern and central corridors, focusing on coal transportation. By 2030, railway infrastructure, including tracks, stations, and operational facilities, is planned for gradual development. One of these projects is the railway line between Banjarmasin and Martapura, with a 1435 mm track gauge specification.

B. Criteria for Determining Railway Alignment

Several criteria are used to evaluate and select the best railway alignment, including:

1. Total track length
2. River crossings
3. Elevated track sections
4. Number of level crossings
5. Track length passing through residential areas

C. Geometric Design and Railway Construction

Geometric design and construction of the railway line between Banjarmasin – Martapura refers to the following references:

1) Ministerial Regulation No. 60 of 2012 on Technical Requirements of Railway Lines [5].
2) Ministerial Regulation No. 29 of 2011 concerning Technical Requirements of Railway Buildings [6].
3) Ministerial Regulation No. 36 of 2011 concerning Intersecting and/or Intersecting Between Railway Lines and Other Buildings [7].
4) Ministerial Regulation No. 78 of 2014 concerning Cost Standards in the Environment of the Ministry of Transportation [8].
5) PJKA Service Regulation No. 10 of 1986 concerning Rail Road Construction Planning [9].
6) Book "Rail Road" [10].
7) Other literature that can support the completion of the study.

METODOLOGY

The flowchart for the geometric design of the railway line between Banjarmasin and Martapura is shown in Figure 1.

A. Problem Identification

This stage involves identifying issues in the study area. The primary problem is the lack of sufficient public transportation options in South Kalimantan, specifically in Banjarmasin, Syamsudin Noor Airport, Banjarbaru, and Martapura. The existing options cannot meet the increasing demand for interregional travel, necessitating the construction of a railway line as an alternative public transportation mode.

B. Literature Study

A literature review is conducted by gathering information from regulations and references relevant to railway line design. This review provides the criteria required for the design process.

C. *Data Collection*

The data needed in designing the railway line between Banjarmasin - Martapura is in the form of secondary data, including:

1. Map the terrain to determine land use and availability.
2. Contour maps for elevation details.

Table 1 Recapitulation of scoring results for each alternative route

Criteria	Alternative 1		Alternative 2		Alternative 3		Alternative 4	
Total path length (km)	44,4	2	42,9	4	45,1	1	43,1	3
Intersection with river (meters)	182	1	71,7	4	92,1	2	74,5	3
Elevated path length (km)	25,6	2	23	4	24,8	3	26	1
Number of level crossings (points)	11	2	9	4	10	3	12	1
Length of path passing through settlements (km)	16,8	1	16,4	3	15	4	16,5	2
Total Score		8		19		13		10

Figure 2 Trase planned railway line between Banjarmasin – Martapura

3. Railway plan data
4. Brochures of bearings, rails, tethers, and switchs.

Inflation rate data

D. Design Criteria

The design criteria used in this design include:

1. Railroad width = 1435 mm
2. Railroad classes = class I
3. Plan speed = 100 km/h
4. Train series = KRDE Sulawesi

E. Data Analysis

Based on the design criteria that have been determined and the data collected, data analysis can then be carried out. The data analysis carried out consisted of:

1) Determination of trace alternatives
2) Geometric design of railway roads
3) Railway road construction design
4) Calculation of the cost budget plan

ANALYSIS AND DISCUSSION

A. Determination of Trace Alternatives

To determine the trace of the railway line, there are 4 (four) alternative routes. The selection of trace is done by providing a score for each trace. The selected trace is the one with the highest assessment results. The selected trace will be used in the geometric design of the railway line between Banjarmasin-Martapura. A recapitulation of the scoring results for each alternative trace can be seen in table 1. Based on the results of the analysis, selected alternative trace was obtained, namely alternative 2 shown in figure 2.

B. Calculation of Azimuth Angle (α) and Bend Angle (Δ)

In the calculation of azimuth angle and bend angle, examples of calculations at the Start, PI1, and PI2 points are used shown in Figure 3.

1) Azimuth Angle (α)

a) Starting Point – PI1

$$\alpha_1 = \text{arc.tan}\left(\frac{\Delta X}{\Delta Y}\right) = \text{arc.tan}\left(\frac{2997{,}538}{91{,}021}\right) = 86{,}261°$$

b) PII – PI2 (Quadrant II)

$$\alpha_2 = 180 + \text{arc.tan}\left(\frac{\Delta X}{\Delta Y}\right)$$

$$= 180 + \text{arc.tan}\left(\frac{1397{,}584}{-34{,}894}\right) = 180 - 88{,}570$$

$$= 91{,}430°$$

2) Bend Angle (δ)

$$\Delta = \alpha_2 - \alpha_1 = 91{,}430 - 86{,}261 = 3{,}17°$$

C. Horizontal Alignment Design

The horizontal arrangement uses *Full-Circle* (FC) and *Spiral-Circle-Spiral* (SCS) arch types. For the calculation of the FC curve an example is used on PI1 with the following parameters:

Δ = 3.17°

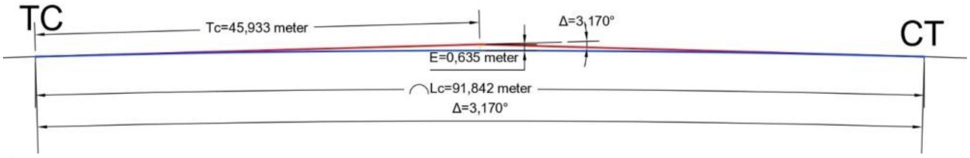

Figure 3 FC arch scheme on PI1

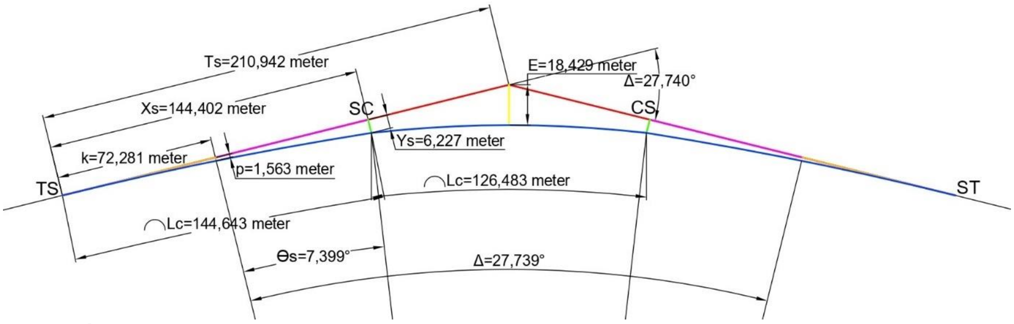

Figure 4 SCS curvature scheme on PI2

R design = 1660 meters
V design = 100 km/h

1) Rail Superelevation (h)

$$h = 8{,}1 \times \frac{(V\ design)^2}{R} = 8{,}1 \times \frac{(100)^2}{1660}$$

$$= 48{,}795\ mm\ (< 150\ mm)\ \text{(OK)}$$

2) Tangent Length (Tc)

$$Tc = R \times tg\left(\frac{1}{2}\Delta\right) = 1660 \times tg\left(\frac{1}{2}(3{,}17)\right)$$

$$= 45{,}933\ meter$$

3) Curve Length (Lc)

$$Lc = \left(\frac{\Delta\pi}{180}\right) \times R = \left(\frac{(3{,}17)\pi}{180}\right) \times 1660$$

$$= 91{,}843\ meter$$

4) Total external distance from PI to center of circle arch (Ec)

$$E = \left(\frac{R}{\cos\left(\frac{1}{2}\Delta\right)}\right) - R$$

$$= \left(\frac{1660}{\cos\left(\frac{1}{2}(3{,}17)\right)}\right) - 1660$$

$$= 0{,}635\ meter$$

5) Track Widening (p)

$$p = \frac{4500}{R\ design} - 8 = \frac{4500}{1660} - 8 = -5{,}289\ mm$$

For the calculation of the SCS curvature an example is used on PI2 with the following parameters:

Δ = 27.74°
R plan = 560 meters
V plan = 100 km/h

1) Rail Superelevation (h)

$$h = 8{,}1 \times \frac{(V\ design)^2}{R} = 8{,}1 \times \frac{(100)^2}{560}$$

$$= 144{,}643\ mm\ (< 150\ mm)\ \text{(OK)}$$

2) Minimum Transition Curve Length (Ls)

$$Ls = 0{,}01 \times h \times V = 0{,}01 \times 144{,}643 \times 100$$

$$= 144{,}643\ meter$$

3) Transition Curved Angle (θs)

$$\theta s = \frac{90 \times Ls}{\pi \times R} = \frac{90 \times 144{,}643}{\pi \times 560} = 7{,}399°$$

4) Curve Length (Lc)

$$Lc = \frac{(\Delta - 2\theta s) \times \pi \times R}{180}$$

$$= \frac{\left(27{,}743 - 2(7{,}399)\right) \times \pi \times 560}{180}$$

$$= 126{,}484\ meter$$

5) Shift of Circular Arc Relative to Tangent Angle (p)

$$p = \frac{Ls^2}{6 \times R} - R \times (1 - \cos(\theta s))$$

$$= \frac{144{,}643^2}{6 \times 560} - 560 \times (1 - \cos(7{,}399))$$

$$= 1{,}563\ meter$$

6) Distance from TS to Point p (k)

$$k = Ls - \frac{Ls^3}{40 \times R^2} - (R \times \sin(\theta s))$$

$$= 144{,}643 - \frac{144{,}643^3}{40 \times 560^2} - (560 \times \sin(7{,}399))$$

$$= 72{,}281\ meter$$

7) Distance from TS to PI (Ts)

$$Ts = (R + p) \times tg\left(\frac{1}{2}\Delta\right) + k$$

$$= (560 + 1{,}563) \times tg\left(\frac{1}{2}(27{,}743)\right) + 72{,}281$$

$$= 210{,}942\ meter$$

8) Total External Distance (E)

$$E = \frac{(R + p)}{\cos\left(\frac{1}{2}\Delta\right)} - R = \frac{(560 + 1{,}563)}{\cos\left(\frac{1}{2}(27{,}743)\right)} - 560$$

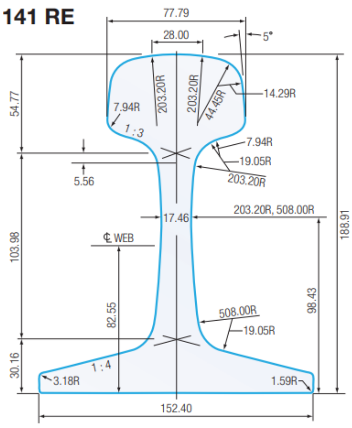

Figure 5 141RE rail dimensions

$= 18{,}429\ meter$

9) Distance from TS to the Projection of the Center (Xs)

$$Xs = Ls \times \left(1 - \frac{Ls^2}{40 \times R^2}\right)$$

$$= 144{,}643 \times \left(1 - \frac{144{,}643^2}{40\ x\ 560^2}\right)$$

$$= 144{,}402\ meter$$

10) Distance from SC to the Tangent Projection (Ys)

$$Ys = \frac{Ls^2}{6 \times R} = \frac{144{,}643^2}{6 \times 560} = 6{,}227\ meter$$

11) Track Widening (p)

$$p = \frac{4500}{R\ rencana} - 8 = \frac{4500}{560} - 8 = 0{,}036\ mm$$

12) Total Curve Length (Ltot)

$$Ltot = Lc + 2Ls = 126{,}484 + 2(144{,}643)$$
$$= 415{,}77\ meter$$

The FC and SCS curved schematics can be seen through Figure 3 and Figure 4.

D. Vertical Alignment Calculation

For the design of vertical alignment, a maximum gradient of 10‰ is used for open track sections, while 1.5‰ is applied for station areas. A sample calculation for vertical curves is provided at STA 0+500 with the following parameters:

V design = 100 km/h
R design = 6000 meters
Elevation design = +8,000 meters
G1 = 0.00% = 0.00‰
G2 = 0.8% = 8.00‰

1) Xm $= \frac{R}{2} \times (G1 - G2)$

= = -24,000 meters$\frac{6000}{2} \times (0{,}00\% - 0{,}80\%)$

2) Ym = $\frac{R}{8} \times (G1 - G2)^2$

= 0.048 meters$\frac{6000}{8} \times (0{,}00\% - 0{,}80\%)^2$

3) Lv = 48,000 meters2 $\times\ Xm\ 2 \times (-24{,}000)$

4) PLV elevation $= Elevasi\ PPV - \frac{G1}{100} \times \frac{1}{2} \times Lv$

= = +8,000 meters8 $- \frac{0{,}00\%}{100} \times \frac{1}{2} \times 48$

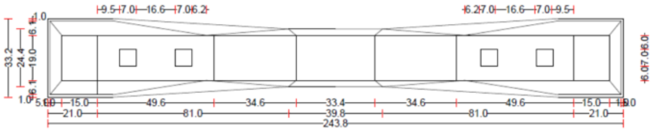

Figure 6 S-35 type concrete sleepers

5) PTV elevation $= Elevasi\ PPV - \frac{G2}{100} \times \frac{1}{2} \times Lv$

= +7,998 meters8 $- \frac{0{,}80\%}{100} \times \frac{1}{2} \times 48$

E. Rail Dimension Planning

The rail dimension design uses 141RE rail type, planned for a design speed of 125 km/h. The dimensions of the 141RE rail are illustrated in Figure 5.

The following are the parameters for the calculation of rail dimension planning:

Rail type = 141 RE
Moment of inertia of the X-axis (Ix) = 4181 cm^4
Weight = 69.79 kg/m
Cross-sectional area (S or A) = 89.01 cm^2
Distance of bottom edge to neutral line (G) = 98.43 mm
Base moment resistance (Zx Base) = 475 cm^3
Maximum axle load = 22.5 tons
Steel Modulus of Elasticity (E) = 2.1 x 106 kg/cm^2
Rail Bed Modulus of Elasticity (k) = 180 kg/cm^2
Rail Allowable Stress (σ-permission) = 1325 kg/cm^2
Base Rail Allowable Stress (Si) = 1042.3 kg/cm^2

1) Dynamic Wheel Load (Pd)

$$Ps = \frac{Pgandar}{2} = \frac{22500}{2} = 11250\ kg$$

$$Ip = 1 + 0{,}01\left(\frac{V\ rencana}{1{,}609} - 5\right)$$

$$= 1 + 0{,}01\left(\frac{125}{1{,}609} - 5\right) = 1{,}72688$$

$$Pd = Ps \times Ip = 11250 \times 1{,}72688 = 19427{,}401 \text{ kg}$$

2) *Dumping Factor* (λ)

$$\lambda = \sqrt[4]{\frac{K}{4 \times E \times Ix}} = \sqrt[4]{\frac{180}{4 \times (2{,}1 \times 10^6) \times 4181}}$$
$$= 0{,}00846\ cm$$

3) Maximum Moment (Ma)

$$Mo = \frac{Pd}{4 \times \lambda} = \frac{19427{,}401}{4 \times 0{,}00846} = 574019{,}228\ kg.cm$$

$$Ma = 0{,}85 \times Mo = 0{,}85 \times 574019{,}228\ kg.cm$$
$$= 487916{,}344\ kg.cm$$

4) Review of Allowable Stress (Si)

$$Sbase = \frac{Ma}{Wb} = \frac{487916{,}344}{475}$$

$$= 1027{,}192\ kg/cm^2$$
$$(< 1042{,}3\ kg/cm^2)\ (OK)$$

5) Review of Stress due to Moment (σmoment)

$$\sigma_{momen} = \frac{Ma \times Yb}{Ix} = \frac{487916{,}344\ x\ 9{,}843}{4181}$$
$$= 1148{,}663\ kg/cm^2$$

6) Review of Stress due to Temperature Change

$$l = \frac{E.A.\alpha.\Delta T}{r}$$

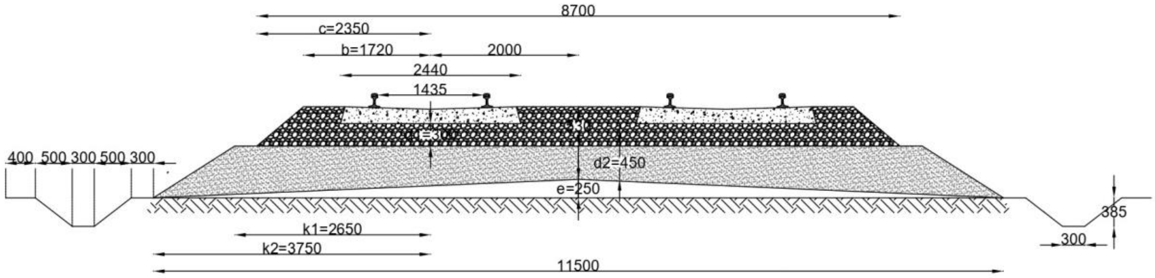

Figure 7 Cross-sectional dimensions of rail roads

Table 2 Results of calculating the cross-sectional dimensions of the railroad.

Road class	V Maks (km/jam)	d1 (cm)	b (cm)	c (cm)	k1 (cm)	d2 (cm)	e (cm)	k2 (cm)
I	120	30	172	235	265	45	25	375

$$= \frac{(2{,}1 \times 10^6)(89{,}01)(0{,}000015)(38-25)}{450}$$
$= 80{,}999\ meter$
$L = 2 \times l = 2 \times 80{,}999 = 161{,}998\ meter$
$\Delta L = l \times \alpha \times \Delta T$
$= 80{,}999 \times 0{,}000015 \times (38-25)$
$= 0{,}016\ meter = 1{,}579\ cm$
$$Ss = \frac{E.\Delta L}{L} = \frac{(2{,}1 \times 10^6)(1{,}579)}{200(100)}$$
$= 165{,}846\ kg/cm^2$

7) Review of Clearance Voltage (σijin)

$\sigma_{momen} + Ss < \sigma_{ijin}$

$1148{,}663\ kg/cm^2 + 165{,}846\ kg/cm^2 <$ $1325\ kg/cm^2$
$1314{,}509\ kg/cm^2 < 1325\ kg/cm^2\ (OK)$

F. Bearing Planning

In this design, the type of bearing to be used is the S-35 concrete bearing which is a product of PT. Wijaya Karya Beton Tbk shown in Figure 6, with a distance between bearings as far as 60 cm.
The specifications of S-35 concrete sleepers include:

Bearing length = 2440 mm

Concrete quality = 60 MPa

Design bending moment:
- Under the rails = +2300 kg.m and -1500 kg.m
- Center bearing = +1300 kg.m and -2100 kg.m

Bearing moment of inertia (I)
- Under the rails = 22115.551 cm4
- Center bearing = 13247.311 cm4

Modulus of elasticity (E) $= 6400 \times \sqrt{f'c}$

$= 6400 \times \sqrt{600}$
$= 156767{,}3435\ kg/cm^2$

Dumping factor (λ) = $\sqrt[4]{\frac{K}{4 \times E \times I}}$
- Under the rails = 0.01067 cm
- Center bearing = 0.01213 cm

Distance of axle to bearing edge = 210 + 1/2 (496)
= 458 mm
½ distance between rail axles =1/2(496) + 346 + 1/2(334) = 761 mm

1) Load entering the bearing (Qd)

$\text{Qd} = 60\% \times \text{Pd}$
$= 60\% \times 19427$
$= 11656{,}440$ k

2) Moment under the rail (C/D moment)

$$= \frac{Q}{4\lambda_1} \times \frac{1}{sinh\lambda_1 L + sin\lambda_1 L} \times \begin{bmatrix} (2cosh^2\lambda_1 a \times (cos2\lambda_1 c + cosh\lambda_1 L)) \\ -(2\cos^2\lambda_1 a \times (cosh2\lambda_1 c + cos\lambda_1 L)) \\ -(sinh2\lambda_1 a \times (sin2\lambda_1 c + sinh\lambda_1 L)) \\ -(sin2\lambda_1 a \times (sinh2\lambda_1 c + sinh\lambda_1 L)) \end{bmatrix}$$
$= 273017{,}929 \times 11 \times 0{,}00220$
$= 6592{,}157\ kg.cm\ (< 230000\ kg.cm)(OK)$

3) Moment in the center of the bearing (Moment O)

$$= -\frac{Q}{2\lambda_2} \times \frac{1}{sin\lambda_2 L + sinh\lambda_2 L} \times \begin{bmatrix} (sinh\lambda_2 c \times (sin\lambda_2 c + sin\lambda_2(L-c)) \\ +(sin\lambda_2 c \times (sinh\lambda_2 c + sinh\lambda_2(L-c)) \\ +(cosh\lambda_2 c \times (cos\lambda_2(L-c)) \\ -cos\lambda_2 c \times (cosh\lambda_2(L-c) \end{bmatrix}$$
$= -480373{,}067 \times 9{,}677 \times 0{,}00066$
$= -3071{,}993\ kg.cm\ (< -210000\ kg.cm)\ (OK)$

Furthermore, calculations were also made to review whether a bearing distance of 60 cm could be applied in this design. The parameters required in the calculation include:
Pairing distance between bearings (L) = 60 cm (2a)
Upper reply to coefficient (C) = 8 (for cricket reply)
Rail moment of inertia (Ix) = 4181 cm^4

1) Rail Bending Coefficient (B)

$$B = \frac{6 \times E \times Ix}{a^3} = \frac{6 \times (2{,}1 \times 10^6) \times 4181}{30^3} = 1951133\ kg$$

2) Area of bearing plane (A)

$$A = 2 \times jarak\ bantalan \times \frac{1}{2}\ panjang\ bantalan$$
$$= 2 \times 60 \times \frac{1}{2}(244) = 14640\ cm^2$$

3) Bearing coefficient (D)

$$D = \frac{1}{2} \times 0{,}90 \times A \times C = \frac{1}{2} \times 0{,}90 \times 14640 \times 8$$
$= 52704\ cm^2$

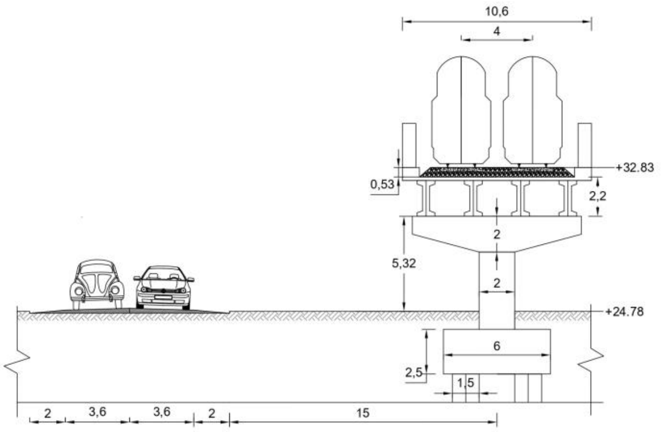

Figure 8 Transverse cut of elevated line construction.

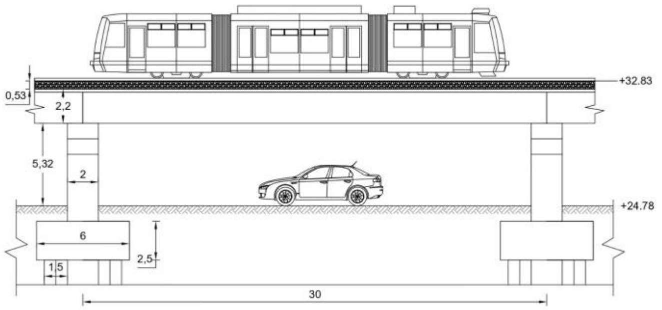

Figure 9 Longitudinal cut of elevated line construction

4) Coefficient of Conditions (k)

$$k = \frac{B}{D} = \frac{1951133{,}333}{52704} = 37{,}021\ kg/cm^2$$

5) Maximum Moment (Mmax)

$$M_{max} = \frac{(8 \times k) + 7}{(4 \times k) + 10} \times 0{,}25 \times Ps \times L$$
$$= \frac{(8 \times 37{,}021) + 7}{(4 \times 37{,}021) + 10} \times 0{,}25 \times 11250 \times 60$$
$$= 323622{,}741\ kg.cm$$

6) Basic Prisoner (Wb)

$$W_b = \frac{Ix}{Yb} = \frac{4181}{9{,}843} = 424{,}769\ cm^3$$

7) Installation Distance Requirements Between Bearings

$$\sigma ijin \geq \frac{M_{max}}{W_b}$$
$$1325\ kg/cm^2 \geq \frac{323622{,}741}{424{,}769}$$
$$1325\ kg/cm^2 \geq 761{,}880\ kg/cm^2\ (OK)$$

G. Rail Fastening Components

The rail fastener serves to anchor the rail to the bearing. The type of fastener used in this design is the KA Clip fastener *produced* by PT. Pindad (Persero).

H. Design of Ballast and Sub-Ballast

The cross-sectional dimensions of the railway track specified in Ministerial Regulation No. 60 of 2012 are designed for a track gauge of 1067 mm. Therefore, adjustments are needed to accommodate the 1435 mm gauge. The adjustment for the distance from the track centerline to the edge of the upper ballast layer (b) is calculated based on the following parameters:
Bearing length (L) = 244 cm
Top reply shoulder width (X) = 50 cm

Figure 10 Ijo Tunnel design concept

$$b > 0{,}5L + X$$
$$> 0{,}5(244) + 50$$
$$> 172\ cm$$

In addition, the thickness value of the lower reply layer (d2) is also still in the range between 15-50 cm so it needs to be reviewed how thick the lower ballast layer can be used. The parameters required for the calculation of the thickness of the lower ballast layer include:
Bearing bottom width (be) = 870 cm
Bearing elasticity modulus (E)= 159358.715 kg/cm^2
Bearing moment of inertia (Ix)= 13247.311 cm^4
Dynamic load (Pd) = 19427.401 kg
Distance of axle to edge of bearing (a) = 45.8 cm
1/2 distance between axles (c) = 76.1 cm
Top dressing layer thickness (d1) = 30 cm
Modulus of reaction retaliation (to) = 3 kg/cm^2
Base ground voltage (σ-t) = 1.2 kg/cm^2

1) Voltage under bearing (σ1)

$$k = be \times ke = 870 \times 3 = 2160\ kg/cm^2$$
$$\lambda = \sqrt[4]{\frac{k}{4 \times E \times I}}$$
$$= \sqrt[4]{\frac{2160}{4 \times 159358{,}715 \times 13247{,}311}}$$
$$= 0{,}02358\ cm^{-1}$$
$$\sigma_1 = \left(\frac{60\%\ Pd\ \lambda}{2b} \times \frac{1}{sinh\lambda L + sin\lambda L} \times \left(2cosh^2\lambda a\ x\ (cos2\lambda c + cosh\lambda L)\right)\right) - \left(2\ cos^2\ \lambda a \times (cosh2\lambda c + cos\lambda L)\right) - \left(sinh2\lambda a \times (sin2\lambda c + sinh\lambda L)\right) - (sin2\lambda a \times (sinh2\lambda c + sinh\lambda L)$$
=(0,15796 × 4,979 x 4,008)+3,992+(-0,00143) -(-0,00143)
$$= 7{,}145\ kg/cm^2$$

2) Backlash layer thickness (d)

$$d = \sqrt[1{,}35]{\frac{58 \times \sigma 1}{\sigma t}} - 10 = \sqrt[1{,}35]{\frac{58 \times 7{,}145}{1{,}2}} - 10$$
$$= 74{,}252\ cm$$

3) Thickness of the lower ballast layer (d2)

$$d2 = d - d1 = 74{,}252 - 30$$

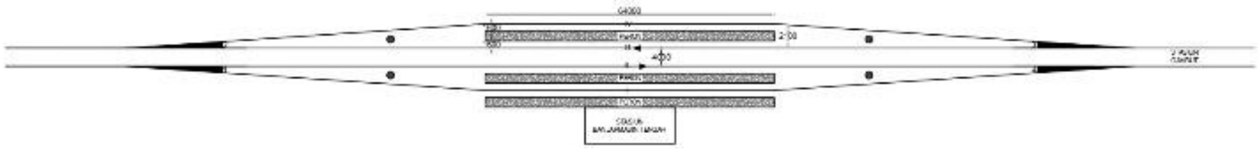

Figure 11 Typical emplacement stations

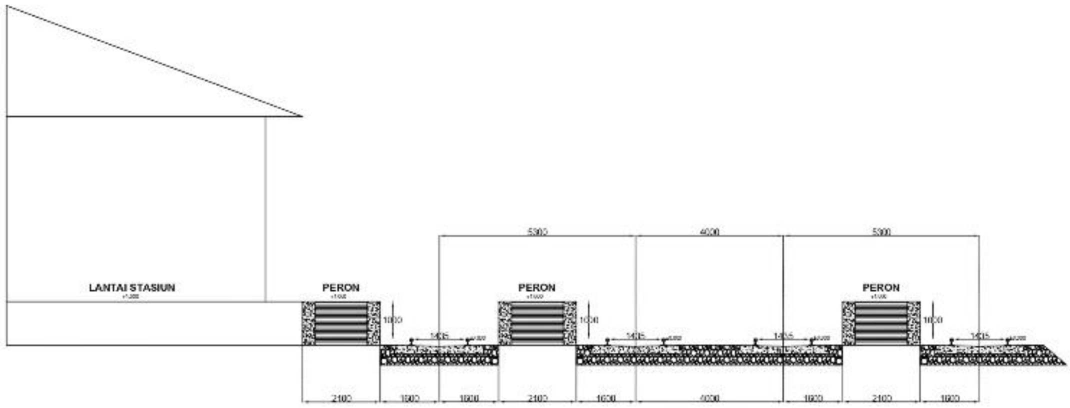

Figure 12 Cross-section of the platform

$= 44{,}252\ cm$

$= 45\ cm\ (15\ cm < d2 < 50\ cm)(OK)$

The cross-sectional dimensions of the railroad after adjustment are shown in Table 2 and Figure 7.

I. Switch Planning

Switches are used to divert trains from one rail to another. The design will use a *type-800:15* base turnout switch produced by *Rail Corp* for rail roads with a *gauge width of* 1435 mm.

J. Quarries and Heaps

Based on the calculation of excavation and stockpile volumes with the *AutoCAD Civil 3D* auxiliary program, the excavation volume was 1,278,870.64 m^3 and the stockpile volume was 260,461.17 m^3.

K. Tunnel Planning

In this design, there are several segments of the path through hilly areas, so it will cause deep digging, and it is feared that it will become a water reservoir. Therefore, it is necessary to build tunnels in certain segments of the railway line. In planning this tunnel, an example of the design concept of the Ijo Tunnel located in Kebumen Regency, Central Java was used. The construction of this tunnel is horseshoe-shaped with a diameter of 9 meters and *reinforced* concrete lining with a thickness of 30 cm and 35 cm. This tunnel is designed for *double track* railway lines. The Ijo Tunnel is shown in Figure 10.

L. Elevated Line Construction Planning

To reduce the number of crossings and avoid excessive land acquisition, this design will use 2 (two) types of railway structures, namely at-grade and elevated. The type of elevated structure to be used is a prestressed concrete bridge with a cross section I (prestressed concrete girder viaduct I section beam) which was previously designed by the JICA Study Team in the design of the Karachi Circular Railway [11] with several adjustments. The structure has a span length of 30 meters and a construction height of 2.2 meters. Elevated lane construction planning must meet the minimum height limit of highway free space, which is 5,1 meters. The planned construction of the elevated line can be seen in Figure 8 and Figure 9

M. Emplacement and Platform Planning

In designing station emplacements, platform length, platform width, and effective length are required. This design uses a high platform type with a series of trains planned for KRDE Sulawesi. The parameters required for emplacement and platform planning include:

Passenger capacity (V) = 250 people
Length TEC1 = 20950 mm
Length M = 20950 mm
Network liaison = 0.5 meters
Load factor = 80%

1) Platform Length (Lp)

$$Lp = M\ length + (2\ x\ TEC1\ length) + (2\ x\ Network\ liaison)$$
$$= 20{,}950 + (2\ x\ 20{,}950) + (2\ x\ 0{,}5)$$
$$= 63{,}85\ meter\ \approx 64\ meter$$

2) Platform Width

$$b = \frac{0{,}64\ m^2/person\ \times\ V\ \times\ LF}{Lp}$$
$$= \frac{0{,}64\ m^2/person\ \times\ 250\ \times\ 80\%}{63{,}85}$$
$$= 2{,}005\ meter\ \approx 2{,}1\ meter\ (> 2\ meter)\ (OK)$$

3) Effective Length

$$Lp = Length\ M + (2\ \times\ Length\ TEC1) + (2\ \times\ Network\ liaison) + safety\ factor$$
$$= 20{,}950 + (2\ \times\ 20{,}950) + (2\ \times\ 0{,}5) + 20$$
$$= 83{,}85\ meter\ \approx 84\ meter$$

The results of station and platform emplacement planning can be seen in Figure 11 and Figure 12.

N. Cost Budget Plan Calculation

The cost budget plan is calculated using the unit price of work based on Ministerial Regulation No. 78 of 2014 which is equivalent using the inflation rate so that the unit price of work is obtained in the plan year. After calculating the volume and getting the equivalence of the unit price of work in 2023, next can be drawn up in a cost budget plan. Based on calculations, the budget for the construction of the railway line between Banjarmasin - Martapura is Rp31,333,291,269,000.00.

CONCLUSION AND SUGGESTION

A. Conclusion

Based on the results of the geometric design of the railway line between Banjarmasin - Martapura, the following conclusions can be drawn:

1) Geometric Design of Railway Lines
Path length = 42.94 km
Railroad width = 1435 mm
Railroad classes = class I
Plan speed = 100 km/h
Path type = *double track*
Horizontal alignment
- Number of PIs = 15 dots
- R plan = 1660 meters (FC)
  560 meters (SCS)

Vertical alignment
- Number of PVI = 45 dots
- R plan = 6000 meters
- Agility = 1% (free lane)
  0.15% (emplacement)

2) Railway Road Construction
Rail type = 141RE
Bearing type = concrete S-35 PT WIKA Beton
Bearing distance = 60 cm
Fastening type = KA *Clip*
Bold Reply = 30 cm
Bold sub reply = 45 cm
Shoulder width Reply = 50 cm
Sub reply shoulder width= 30 cm
Switch = *Base Turnout Type*-800:15
Excavations *(cut)*= 1,278,870.64 m3
Heap *(fill)* = 260,461.17 m3
Construction *elevated* = prestressed concrete bridge cross section I
Tunnel = horseshoe tunnel
Platform length = 64 meters
Platform width = 2.1 meters
Effective length = 84 meters

3) Cost Budget Plan
The cost required in the construction of the railway line between Banjarmasin - Martapura is Rp31,333,291,269,000.00.

B. Suggestion

Suggestions for geometric design of the railroad between Banjarmasin – Martapura include:

1) In determining alternative trace, a more detailed analysis can be carried out by considering the weight of the criteria.
2) The geometric design of the railway still requires further review in accordance with applicable regulations.
3) The determination of the Sulawesi KRDE train type, station emplacement shape, elevated construction, and tunnel design require more detailed analysis to produce more accurate planning.
4) Further analysis of train wheel wear, geotechnical studies, and drainage is needed so that the design is designed more precisely and accurately.
5) The auxiliary program used in this study is still limited to *the student version*, so it is hoped that in the future it can use a professional license.

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