

Design and Cost Analysis of New Railway Reactivation Planning in Madiun-Ponorogo, East Java, Indonesia

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Abstract

The planning of the railway track affected the layout planning of the city area and optimizing development. The purpose of this research is to understand geometry and trace planning to be accurately designed, and visualization in three dimensions to facilitate modelling in the field. In this study, data collection covers primary and secondary. The analysis used for plotting contour was software infraworks. Geometry planning the railway is using software AutoCAD Civil 3d, three-dimensional visualization modelling using software infraworks. Based on the election results of trace, the selected trace alternative is 57+599 kilometers of Madiun until Slahung at 110 km/ h operating rate. The railroad class classifications, and in the study are 21 horizontal arms that were systematically calculated using a software AutoCAD civil 3d and calculation analysis based on the decision of the Minister of Transportation No. 60 of 2012 and the official Regulation of the Railway Company No.10 in 1986.

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I. INTRODUCTION

Based on the revised National Railway Master Plan (RIPNAS) in 2018, the Directorate General of Railways of the Ministry of Transportation explained that the objectives of developing railway networks and services to be achieved by 2030 include the national railway reaching 12,100 km (spread across the islands of Java, Bali, Sumatra, Sulawesi, Kalimantan, and Papua)[1]. Planning for reactivation and improvement of the railroad tracks covering the Madiun - Slahung route is designed to be built from 2025 to 2030. The purpose of reactivation needs to be carried out on the Madiun - Slahung route[2]. Which is intended to reactivate the Madiun - Slahung railway line, which will be the link between the cities[3]. Madiun - Ponorogo Regency which is based on the fact that the train is more environmentally friendly because it consumes relatively less fuel compared to other modes of

transportation, and can carry more loads in one way compared to different modes of transportation[4]. Developing the potential of villages in Ponorogo Regency and improving the quality of community education that utilizes traffic in the rail transportation mode is a priority for transportation access between Madiun City and Ponorogo Regency which is integrated with the National Railway Master Plan [1][5].

This research has a limitation of the problem that is meant so that this research does not discuss broadly and will be limited by several aspects, namely:

1. The speed of the train plan in this study with an operational 110 km/hour, a maximum speed of 120 km/hour, and using railroad class I.
2. The course made 2 lines by assessing and comparing the tracts.

3. Research planning the best alignment based on assessments and calculating the geometry of the railroad track.
4. The research does not examine demand planning and surveys of the interests of the community around the research location, and it does not review the carrying capacity, congestion, and landslides.
5. The research draws a drainage design but does not calculate the water discharge and volume in the drainage system.
6. The study is located in the Madiun - Slahung route using Infracore and AutoCAD Civil 3D software.
7. The research calculates the volume of excavation and railroad fill, and budget plan, but does not take into account stations, bridges, money orders, level crossings, signaling, and land acquisition.

II. RESEARCH METHODS

Previous research is one of the researchers' preferences for researching so that researchers can multiply the theory used. The following is one of the earlier studies in the form of a journal related to research conducted by researchers. Reactivation Planning for the Kedungjati - Tuntang Railway Line Using Google Earth, Global Mapper, and AutoCAD Civil 3D Compiled by Dhiya Ayu Nuswantari, et al [6]. This study aims to plan railroad geometry and contour adjustment in the field using the three software construction methods with sequential work systems from Google Earth, Global Mapper, and AutoCAD Civil 3D in a structured manner and based on several laws and regulations. The difference between previous research and this research is the previous research using Google Earth software, Global Mapper, and AutoCAD Civil 3D, so this research combines new software that will be used for the animation to get visible results according to the real conditions in the field. The software is Infracore and AutoCAD Civil 3D, while the discussion is both researching and analyzing railroad track planning/reactivation.

Acquisition of research data can be obtained as follows:

1. Primary Data:

The essential primary data in this research can be obtained from direct observation of the condition of the existing railway line, crossing Madiun - Slahung.

2. Secondary Data:

The secondary data needed in this study are as follows:

- a. Planning of Spatial Planning and Regional Government of PMadiun City, PMadiun Regency, and Ponorogo Regency.
- b. Topographic maps, land use, road networks, and geology are used as the basis for making railroad alignment designs.

In the study, data analysis was carried out and divided into five stages to make it easier for researchers to research with the following steps:

First, the researcher will plan the selection of an outline that will be made combined with processing RT&RW data. After processing the data, a survey will be carried out at several existing points and a planned alignment that has been determined by the author[7]. The survey aims to make researchers know directly the conditions in the field that will be used as a railroad alignment[8]. Second, analyzing topographic maps from Infracore software by analyzing topographical maps from Infracore software to AutoCAD Civil 3D, then we will get the contour conditions of the specified area[9]. Third, planning and calculating the geometry of the railroad track includes horizontal alignment, vertical alignment, slopes, railroad structure, maximum speed, railroad classification, and volume calculation of excavations and embankments[8],

[10]. Fourth, the depiction of the structure and drainage of the railroad tracks in the AutoCAD Civil 3D software. The description of the structure and drainage is carried out to obtain detailed perceptions in the railway line. Fifth, the next step after depicting the perceptions is making train track animation in Infracore software, it aims to make train tracks visual according to field condition[4], [11].

III. RESULT AND DISCUSSION

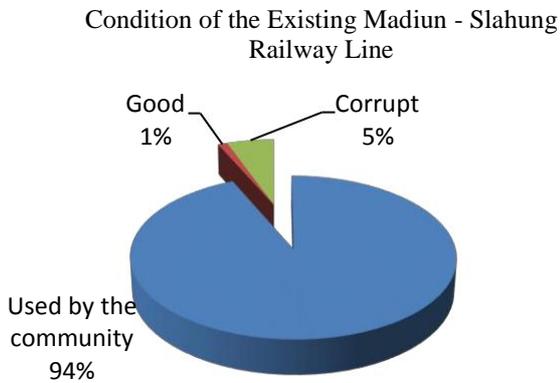


Figure 4. 1 Chart of the condition of the existing railway line.

It can be seen in Figure 4.1 above that most of the existing Madiun - Slahung railway lines have been utilized by the community, some are damaged, and only 1% is still classified as in good condition. The condition of the existing railway line uses a single

track with a spoor width of 1067 mm. The results of the researcher's survey in 2020, the state of the existing Madiun - Slahung railway line has been utilized by the community, while from a social, economic and environmental perspective, the current railway line cannot be reactivated because it will require high costs to free land and conflicts. social (pros and cons) are also increased when there will be land eviction, 5% are damaged because the rail has been lost, and 1% is in good condition, this condition must be reconsidered regarding the old components that are still installed on the route and need to be retested, so that get maximum results.

III. 1 Trace Rating Classification

After all, aspects are calculated, the results are entered into a comparison table between the existing and new alignments so that the alignments can be generated that will be used in the design of the railway line geometry. Trace rating classification can be seen in Table P4.1 at the bottom of this section.

Table 4. 1 Trace Selection Ranking

Land Use	Area of land section 1 (m ²)		Area of land section 2 (m ²)		Area of land section 3 (m ²)	
	Trace 1 (existing)	Trace 2 (New)	Trace 1 (Existing)	Trace 2 (Alternative)	Trace 1 (Existing)	Trace 2 (Alternative)
Rice fields	218.150,9	779.860,7	609134.1	699548.0	575499,75	492.365,9
Community Settlements	675.040	381.975,6	253808.4	249980.2	332.748,8	338.109
Public Cemeteries	580,6	-	-	-	-	-
Plantation	28.064,8	-	58211.7	48383.7	-	-
River	663,7	663,7	806.6	806.6	668,3	690,6

From table 4.1, the results of the classification ranking for the selection of railway lines, one is chosen to be used in the geometric planning of the Madiun - Slahung railway line. The best pathway is

selected based on significant land requirements so that there are no pros and cons with the community around the plot planning.

III.2 Railroad geometry Horizontal Alignment

Table 4. 2 Horizontal Alignment

STA		R(m)	R Minimum with turn (m)	R minimum without switching (m)	Curved Design Speed (Km / h)
Start	End				
00+496	01+381	1594	780	2370	120
02+809	03+653	800	780	2370	120
04+171	05+641	1200	780	2370	120
08+620	10+009	800	780	2370	120
10+909	11+451	350	350	1050	80
11+639	11+830	450	350	1050	80
12+125	12+312	350	350	1050	80
13+111	13+764	800	780	2370	120
15+420	15+735	800	780	2370	120
16+406	16+553	200	200	600	60
16+655	16+809	200	200	600	60
17+236	17+518	400	350	1050	80
17+649	17+913	350	350	1050	80
21+344	22+242	800	780	2370	120
22+344	22+738	350	350	1050	80
23+221.000	25+259.445	780	2370	780	120
25+797.115	30+773.331	800	2370	780	110
30+982.491	35+994.245	780	2370	780	120
36+719.089	37+829.959	350	1050	350	80
39+289,23	39+711,42	350	1050	350	80
42+373,81	42+612,24	550	1650	550	100
50+544,62	50+719,45	660	1050	350	110

III.3 Curve calculation

a. STA 00+496 s/d 05+641

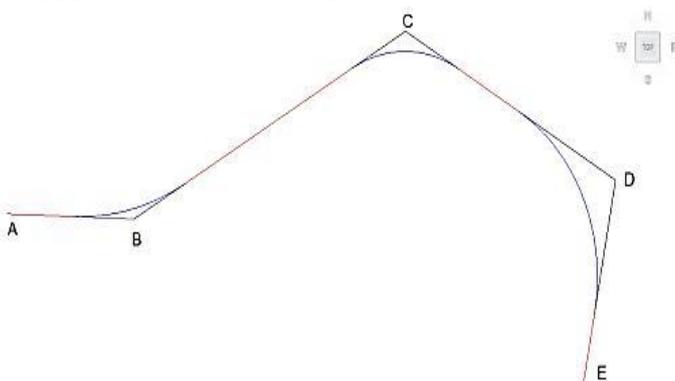


Figure 4. 2 Curved at STA 00+496 s/d 05+641

It is given the coordinates of the rail through points A, B, and C with coordinates:

- A. (X = 557831.224; Y = 9157752.574)
- B. (X = 558226.722; Y = 9157739.303)
- C. (X = 560812.124; Y = 9157963.243)
- D. (X = 562239.845; Y = 9157166.182)
- E. (X = 562214.975; Y = 9157035.139)

1) Based on Permenhub No. 60 of 2012 and PD 10 by calculating the curve at the point B

a) Determination of Minimum Radius (R min)

Centrifugal force:

$$R \text{ min} = 0,076 \times V^2 = 0,076 \times 120^2 = 1094,4 \text{ m}$$

Centrifugal force and carrying capacity of road components (SCS):

$$R \text{ min} = 0,054 \times V^2 = 0,054 \times 120^2 = 777,6 \text{ m}$$

There is no intermediate arch (FC):

$$R \text{ min} = 0,164 \times V^2 = 0,164 \times 120^2 = 2361,6 \text{ m}$$

Then R min is used = 780 m

b) Rail Raising (h)

$$h_1 \text{ normal} = 5,95 \left(\frac{100}{1200} \right) = 5,95 \left(\frac{100}{1200} \right) = 53,75 \text{ mm}$$

$$h_1 \text{ min} = 8,8 \left(\frac{100}{1200} \right) - 53,54 = 8,8 \left(\frac{100}{1200} \right) - 53,54 = 25,96 \text{ mm}$$

$h \text{ maks} = 110 \text{ mm}$, with requirement: $h \text{ min} < h \text{ normal} < h \text{ maks}$
By doing the above calculations, it can be seen that the results are following the provisions with normal h and h min not exceeding h max and h min not exceeding normal h.

c) Transitional Curve (Lh/Ls)

$$h_1 = 0,014 \times 132 = 1,848 \text{ meter, use intermediate } 200 \text{ meter}$$

d) Circle Curve Planning

$$\theta_c = 3^\circ 35' 46,64''$$

$$L_c = 684,74 \text{ m}$$

$$L = 2 \text{ Ls/Lh} + L_c = 2 \times 200 + 684,735 = 1084,74 \text{ m}$$

$$Et = Es = \frac{(R + h)}{2} - R = \frac{(1594 + 104)}{2} - 1594 = 64,57 \text{ m}$$

$$Tt = (R \text{ rencana} + p1) \tan \frac{\theta_c}{2} + k1 = (1594 + 1,04) \tan \frac{3^\circ 35' 46,64''}{2} + 551,56 \text{ mm}$$

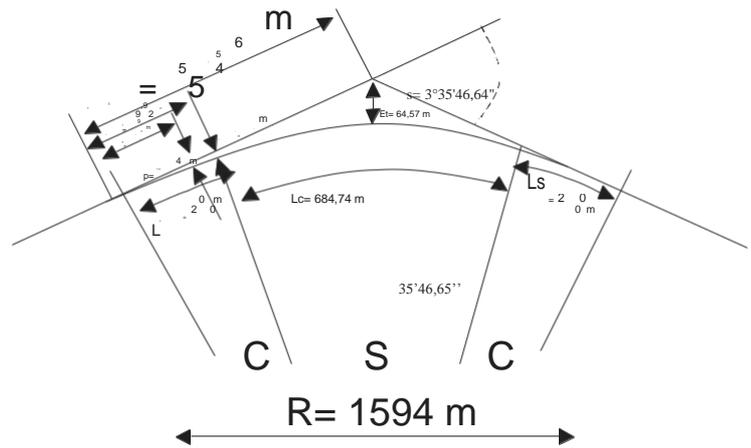


Figure 4.3 Curves Sta 00+496 s/d 01+381

Data for superelevation charts :
Rail plan elevation = 53,75 mm
Ls = 200 m
Lc = 684,74 m

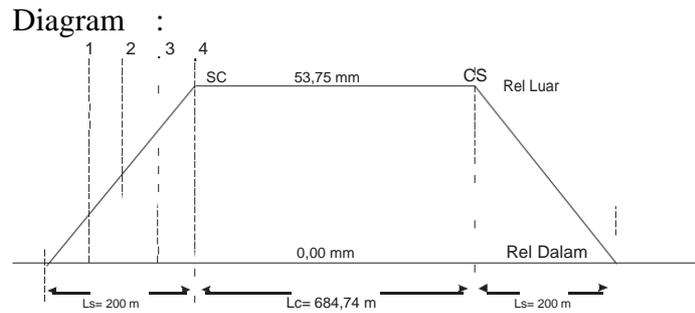


Figure 4. 4 Superelevation Diagram Sta 00+496 s/d 01+381

Change in the rail height of the transitional arch: The transitional arc length considered is the point at 1/4 Ls (point 1), 1/2 Ls (point 2), 3/4 Ls (point 3) dan Ls (point 4).

point 1	53,75 = 13,4375
point 2	53,75 = 26,875
point 3	53,75 = 40,3125
point 4	53,75 = 53,75

Track widening calculation data:
 $R = 1594 \text{ m}$

$w = -5,17 \text{ mm}$, hence no widening is required because $R > 600 \text{ m}$ the required widening is 0 mm.

III. 4 Vertical Alignment

Table 4. 3 Vertical Alignment

Sta	Elevation	Percentage Percent
0+000.00	71.057m	0.00%

0+250.00	71.059m	0.00%
0+500.00	71.059m	0.00%
0+750.00	71.087m	0.01%

0,11 % 0,00 %

71.057m 72.165m

Figure 4. 5 Vertical curve at STA 01+000

V maks = 120 km/jam → R min = 8000

m

Curved B

0,00 % = 0,00 ‰

0,11% = 1,1 ‰

$Q_B = 1,1‰ - 0,00‰ = 1,1‰$ $L_v =$

$Q_B \times R$

$= (1,1/1000) \times 8000$

$= 8,8$ m

$E_v = (R \times Q_B^2) / 8$

$= (8000 \times (1,1/1000)^2) / 8$

$= 0,00121$ m, so it can be seen in Figure

4.6.

III.5 Line Components

Table 4. 5 Bearing Calculations

Component	Unit	total
Distance between bearings	Meter	0,60
Total Lines	Meter	57599
Number of bearings	Piece	95998

Table 4. 6 Anchor Calculation

Component	Unit	total
Number of anchors on one bearing	Piece	4
Total bearing	Piece	95998
Total anchors	Piece	38399
		3

Table 4. 7 Rail Calculations

Component	Unit	total
Rail length (@25 meter)	Meter	25
The total length of the path	Meter	57599
Total rails	Piece	4608

Table 4.5 P to Table 4.8 has taken into account the railroad components that have been planned. With a path length of 57 + 599, the amount is obtained as in the table. Type of track component material based on technical specifications using concrete bearings, e-clip fastening (pendrol), type rail R.54, and drainage dimensions 1200x1000x1000 (in mm).

III.6 Cross Section and Long Section

Figure 4. 6 Vertical Curved Design

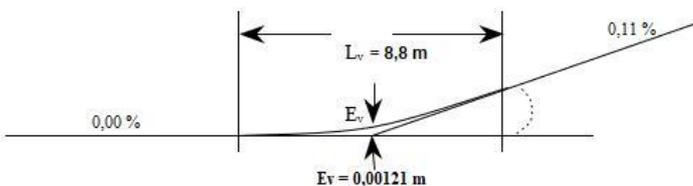


Table 4. 8 Drainage Calculations

Component	Unit	total
Drainage dimensional length (@1,2 meter)	Meter	1,20
The total length of the path	Meter	57599
Total drainage	Piece	95998

III.7 Animations

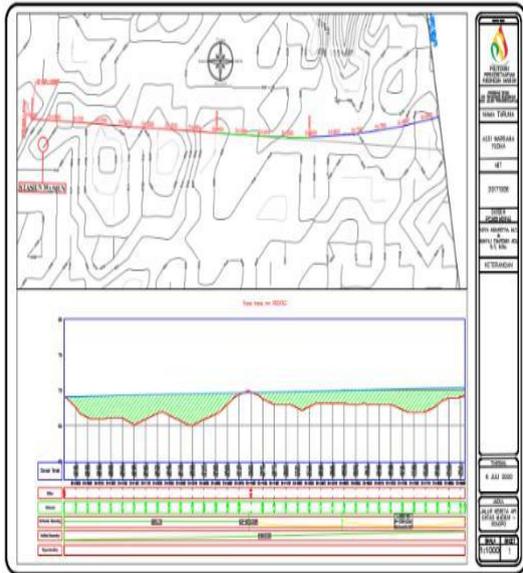


Figure 4.7 Cross Section Details

Figure 4.7 shows a cross-section of the 25-meter intersection on each path that has been made with the required information. The figure shows sta 0 + 250 required for landfilling (ground fill) with a total volume of 2477.71 m³, ballast volume 28.75 m³, sub-ballast volume 59.63 m³, and the elevation of the plan and the elevation of the existing line can be seen. In Figure 4.8 there is a long section image in the path that has been made. In the picture there excavation information in green, fill or heap in red, horizontal alignment, vertical alignment, and superelevation.

is a Madiun station located at km 00 + 000 and the contour intersections in the image with cut or

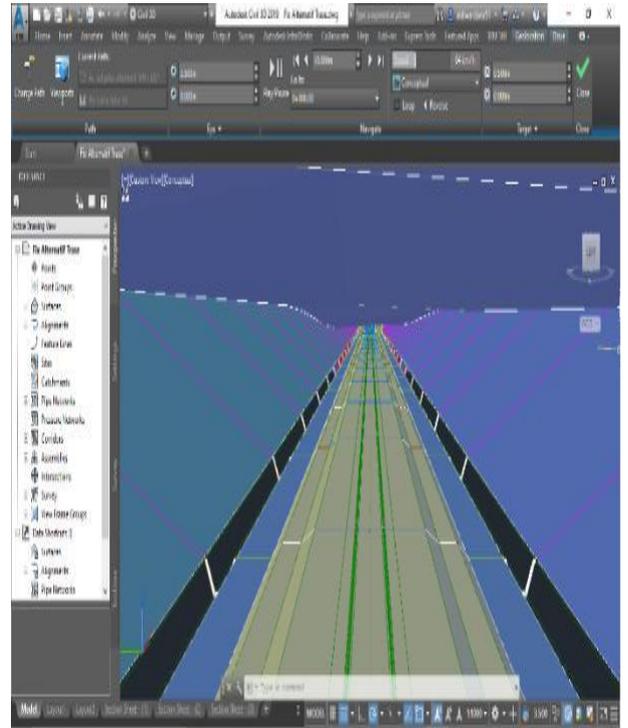


Figure 4. 1 Visual AutoCad Civil 3D

In Figures 4.9P and P4.10, there are visual differences from Infraworks and AutoCAD Civil 3D software. In infraworks software looks 3-dimensional more clearly than in AutoCAD Civil



Figure 4. 8 Visual Infraworks

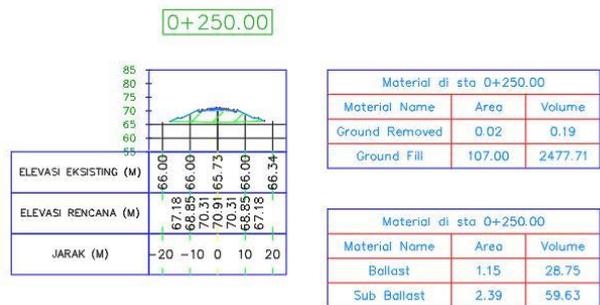


Figure 4. 9

3D. In AutoCAD Civil 3D software, there is only a wireframe that cannot be refined, so the visuals of AutoCad Civil 3D are not optimal for beautifying the results of planning. In contrast, in the Infracore software, you can see city buildings that can be seen clearly to decorate the results of planning.

IV. CONCLUSION

Based on the results of research through analysis and geometric planning of the railroad track between Madiun - Slahung in the discussion, it can be concluded that:

1. After conducting a direct survey to the field, the condition of the existing railroad tracks across Madiun - Dolopo, namely 94% have been used by the community, 5% are damaged because the rail has been lost, and 1% is in good condition. The condition of the existing land across Dolopo - Surodikraman is 95% of the current land condition not visible and has been used by residents, 4% is invisible, damaged and 1% is still visible and sufficient. And the Surodikraman - Slahung route has been used by the surrounding community to become a settlement by 62%, opening land for agricultural activities by 36%. Meanwhile, only 2% of the railroad tracks remain, and the rails are still visible. However, some rails are used as supporting tools and lighting poles in the community.
2. The best alternative alignment proposal is selected based on the ranking table for the alignment selection with the smallest value is line 2 or the alternative line. An alternative route crossing Madiun - Slahung uses an area of rice fields 1,367,949.90 m², community residential land area 1,573,889.50 m², plantation land 48,383.70 dan rivers as complete as 2,160.90 m².
3. Horizontal alignment planning with an operating speed of 110 km/hr. Using railroad class I, and has a flat curve of 21 pieces with radius, namely 1594 m, 1200 m, 800 m, 660 m, 550 m, 450 m, 400 m, 350 m, dan 200 m.
4. Vertical alignment planning using the provisions of railroad class I, the maximum allowable slope is 10 ‰ per mil. Vertical alignment planning in km 00+000 s/d km 08+250 have slopes 0,0‰ per mil until 1,1‰ per mil, di km 08+500 s/d km

14+500 have slopes 1,2‰ per mil up 1,9‰ per mil, di km 14+750 s/d km 15+250 have slopes 1,5‰ per mil until 2,8‰ per mil, di km 15+500 s/d km 17+500 have slopes 3,8‰ per mil until 4,5‰ per mil, di km 17+750 s/d km 20+250 have slopes 07,1‰ per mil until 8,8‰ per mil dan di km 20+500 s/d km 23+230 have slopes 2,1‰. Following Permenhub No. 60 of 2012 concerning the technical requirements of railway lines that the maximum slope on the class I railway is a maximum of 10 ‰ per mil.

5. Drawing cross sections and long sections using AutoCAD Civil 3D software, the researcher tries to display the area count of one cross-section and the volume between two cross-sections with an intersection every 25 m so that it is expected to obtain soil volume that is close to the conditions in the field.
6. Calculating the volume of excavation, stockpile, ballast, and sub balance using AutoCAD Civil 3D software, the researcher obtained a cumulative excavation volume calculation of 3,525,871.52 m³ and a cumulative stockpile volume totalling 3,085,694.44 m³, counterbalance volume of 66,248.41 m³, and sub balance volume of 138,080.99 m³. From this calculation, the planned development requires a lot of lands to be stockpiled.
7. Calculation of railroad components, namely requiring bearings with a total of ± 112,678, requiring fasteners with a capacity of ± 450,713, requiring rails with a total of ± 5,409 units, and requiring drainage with a total of ± 112,678.

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