

ANALYSIS OF CUT-AND-FILL CALCULATIONS USING CIVIL 3D FOR THE BATU TAMBUN ROAD SECTION, NORTH PADANG LAWAS REGENCY

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Abstract

Batu Tambun Road in Simbolon Village, North Padang Lawas Regency, connects surrounding districts but requires systematic geometric planning to improve its technical condition. This study mapped the road corridor using ArcGIS Pro and developed horizontal and vertical alignments with reference to the 2021 Road Geometric Design Guidelines (PDGJ 2021). Coordinates were digitized in Google Earth Pro, supplemented with elevation data through GPS Visualizer, processed in ArcGIS Pro, and integrated into Autodesk Civil 3D. The workflow produced contour mapping, an existing-ground surface, geometric design outputs, longitudinal profiles, cross-sections, and earthwork quantities. The final reported alignment length was 4,733.98 m, with 24 horizontal curves comprising nine full-circle and 15 spiral-circle-spiral curves. Fifteen vertical curves were reported, comprising eight sag and seven crest curves. The design used a speed of 60 km/h, a 7 m carriageway, and 6% superelevation. Calculated cut and fill volumes were 114,028.72 m³ and 162,236.77 m³, respectively, leaving a fill deficit of 48,208.05 m³. The integrated workflow provides a basis for road development planning. Detailed field verification remains necessary before construction.

Keywords: ArcGIS Pro; Autodesk Civil 3D; BIM; GIS; road geometric design.

INTRODUCTION

Road infrastructure supports the movement of people and goods, the distribution of agricultural products, and the development of regional economic activities. Indonesian road legislation defines roads as land-transport infrastructure encompassing the roadway and its associated structures and equipment, subject to the specified exclusions (Republik Indonesia, 2022). Accordingly, road development requires systematic planning that responds to both its transport function and the technical characteristics of the surrounding area. Batu Tambun Road is located in Simbolon Village, Padang Bolak District, North Padang Lawas Regency, North Sumatra. It connects Padang Bolak and Portibi districts and supports community mobility and agricultural distribution. The existing road was described as damaged and irregular, with inadequate geometric planning. These conditions motivated the preparation of a spatially informed design addressing road geometry, driving comfort, and safety.

Research objectives and scope

Geometric design concerns the physical configuration of a road, including its horizontal alignment, vertical alignment, and cross-section. These elements must be coordinated rather than treated as separate drawings, because the selected route and longitudinal profile depend on the terrain. The 2021 Road Geometric Design Guidelines, hereafter PDGJ 2021, provide the principal design reference adopted in this study (Kementerian Pekerjaan Umum dan Perumahan Rakyat [PUPR], 2021).

The study addresses three questions: what mapping outputs can be obtained for the Batu Tambun corridor using geographic information systems; how its horizontal and vertical alignments can be designed; and what geometric design can be produced using the parameters referenced to PDGJ 2021. Its objectives are therefore to map the study area, plan the two alignments, and develop the road geometry using Autodesk Civil 3D. Pavement structural design, traffic-capacity calculations, and level-of-service analysis are outside the stated scope. The intended academic contribution is an application of road geometric design supported by geographic information system (GIS) and

building information modeling (BIM) tools. Its practical contribution is a set of mapping and design outputs that may inform subsequent development of Batu Tambun Road. Detailed field verification remains necessary before the design can be implemented.

LITERATURE REVIEW

Road classification and geometric design criteria

Road classification establishes the framework within which design parameters are selected. Roads are distinguished by purpose, network system, administrative status, function, and usage class. The primary network serves the distribution of goods and services between activity centers, whereas the secondary network serves movement within urban areas. These distinctions are presented with reference to Government Regulation No. 34 of 2006 and Law No. 22 of 2009 (Pemerintah Republik Indonesia, 2006, 2009).

For the case examined here, the design calculations identify a regency road with a local-road function in the primary network, usage Class III, and flat terrain. The infrastructure-provision category used in the vertical design is Jalan Kecil (JKC). This study adopts a 60 km/h design speed and a 7 m carriageway comprising two 3.5 m lanes. These are project design inputs; they are not the results of a traffic-capacity assessment. The technical requirements also refer to the road-design criteria in the 2011 public works regulation (Kementerian Pekerjaan Umum, 2011).

Horizontal and vertical alignment concepts

Horizontal alignment is the plan projection of the road centerline and consists of straight sections and curves. The curve types considered are full-circle (FC) and spiral–circle–spiral (SCS) curves. An FC curve uses a circular arc, whereas an SCS curve inserts a transition spiral at each end of the circular section. Transition curves provide a gradual change in curvature and a location for developing superelevation. The geometric relationships follow the interurban road geometric planning procedure and PDGJ 2021 (Kementerian Pekerjaan Umum, 1997; PUPR, 2021).

Vertical alignment is the longitudinal profile along the centerline. It comprises grades joined by crest or sag curves, with design controls related to sight distance, comfort, terrain, and earthworks. PDGJ 2021 classifies terrain as flat, hilly, or mountainous, according to its terrain-slope criteria. The Batu Tambun calculations adopt the flat-terrain category and assess the grade limits and the space available between adjacent vertical curves (PUPR, 2021). In the integrated workflow, mapping supplies the elevation and contour information required for these geometric decisions. ArcGIS Pro is used to organize and visualize spatial data, while Civil 3D supports existing-ground modeling, alignment development, and the production of design profiles and quantities. This connection between mapping and geometric design is the central focus of the study.

Previous studies and the position of the present research

The literature review considered ten studies covering GIS-based mapping, geometric design, road-condition assessment, and digital modeling. Table 1 summarizes their methods and main results. The studies are complementary: some emphasize the spatial description of existing roads, while others develop geometric solutions and construction-related quantities.

Table 1. Previous road-mapping and geometric design studies

Study	Method or emphasis	Reported output
Malik et al. (2019)	GIS, Google Earth, and Civil 3D integration	A road design of approximately 7.9 km, including curves, elevations, cut, and fill.
Siregar et al. (2024)	GIS and Pavement Condition Index (PCI)	Road-network and damage mapping in Medan Perjuangan, with condition categories based on PCI.
Novriani et al. (2025)	Topographic survey and PDGJ 2021 design	A new-road design addressing grades, curves, and sight-distance requirements.
Al Khozi et al. (2025)	Participatory GIS, field survey, overlay, and network analysis	Indicative spatial mapping for regional planning in Kampung Woslay.
Alifianto (2023)	ArcGIS Pro with EAN, UCL, and HIRARC analysis	Mapping of accident-prone areas to support road-safety decisions.

Study	Method or emphasis	Reported output
Balqis et al. (2023)	Total Station survey and Civil 3D	A 237 m Class III, two-lane, two-way access road, with no horizontal curves and two vertical curves.
Marlianti et al. (2023)	PDGJ 2021, DEM, Global Mapper, and Civil 3D	Eight SCS curves and 13 vertical curves, accompanied by pavement design and a cost estimate.
Al. Afghany et al. (2024)	PDGJ 2021 redesign using alignment and topographic data	Ten SCS curves, 14 vertical curves, and earthwork volumes for the Southern Cross Road corridor.
Adi et al. (2022)	Geometric redesign using PDGJ 2021	Thirty-six horizontal curves, comprising SCS and FC curves, and 15 vertical curves.
Megandari and Wijanarko (2022)	GIS and AutoCAD 3D with GPS and Total Station data	Identification of nonconforming road sections and recommendations for widening at curves.

The Batu Tambun study differs from road-condition and accident-mapping studies by continuing from spatial processing to geometric design. Unlike work that includes pavement structures and detailed cost estimates, its stated scope remains mapping, horizontal and vertical alignment, cross-sectional modeling, and earthwork analysis. Compared with the straight access-road case described by Balqis et al. (2023), it addresses a longer corridor with multiple horizontal curves.

These studies establish the relevance of coordinating terrain mapping and geometric design. Building on the GIS–Civil 3D integration discussed by Malik et al. (2019), the present research applies that workflow to the specific conditions of Batu Tambun Road. Its contribution lies in connecting the mapped terrain with horizontal and vertical design parameters referenced to PDGJ 2021, and in developing the corresponding earthwork quantities for this corridor.

METHOD

Study area, scope, and design inputs

The research was conducted on Batu Tambun Road in Simbolon Village, Padang Bolak District, North Padang Lawas Regency. The study-area description identifies the corridor as STA 0+000–STA 4+861. The completed geometric design is separately reported as 4,733.98 m. Image 1 shows the location map prepared using Google Earth Pro.

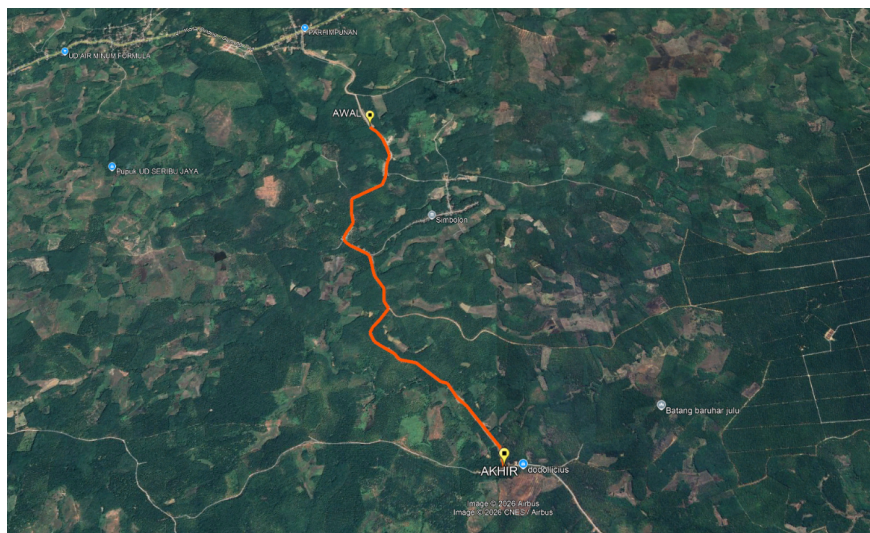


Image 1. Location of the Batu Tambun Road study corridor.

Source: original study, Figure 3.1; Google Earth Pro.

Preparation consisted of identifying the road-planning problem, reviewing relevant literature and standards, determining the required data, and selecting the processing method. Table 2 lists the inputs repeatedly used in the geometric calculations. The classification and selected dimensions are geometric design inputs, not the results of pavement-structure or traffic-service analysis.

Table 2. Adopted geometric design inputs

Parameter	Value or category
Road status and function	Regency road; local road
Network and usage class	Primary road network; Class III
Infrastructure category and terrain	JKC; flat terrain
Design speed, VD	60 km/h
Carriageway and lane widths	7.0 m; 3.5 m per lane
Normal crossfall and design superelevation	3%; 6%
Maximum superelevation cited in the design	8%
Side-friction factor and adopted minimum radius	0.15; 135 m
Maximum longitudinal grade used for checking	6%
Stopping sight distance at the selected speed	85 m
Vertical-curve control values	K = 11 for crest; K = 18 for sag

Values follow the project calculations and the PDGJ 2021 tables used in the study. Subsequent verification is required before construction.

Spatial data acquisition and topographic processing

Spatial data acquisition began with Google Earth Pro. The road location was identified, the initial and final points were marked, and a path was digitized along the existing centerline. The digitized coordinates were saved in KML/KMZ format. The KML file was then uploaded to GPS Visualizer, where the Add Elevation option was selected during conversion to GPX. This step supplied elevation values for the coordinate points used in the subsequent terrain-processing sequence.

In ArcGIS Pro, GPX To Features converted the GPX file into spatial features. The elevation attribute was then used in an inverse distance weighted (IDW) interpolation to produce a raster surface. The documented procedure identifies the input features, elevation field, output raster, cell size, and power parameter. However, the example cell sizes of 5 or 10 m and the typical power value of 2 are not stated as a definitive final processing configuration. The raster was projected to the working coordinate system through Project Raster, with bilinear resampling specified for elevation data. The final coordinate-setting check identifies WGS 1984 UTM Zone 47N. Contour lines were generated from the projected raster, smoothed, labeled by elevation, and combined with hillshade for terrain visualization. The reported Smooth Line tolerance was 50 m, and the hillshade display used 40% transparency.

Table 3. Documented sequence of spatial processing

Stage	Tool or operation	Output
1	Google Earth Pro: placemarks and Add Path	Digitized study location and route
2	GPS Visualizer: Add Elevation; Convert to GPX	Coordinate points with elevation
3	ArcGIS Pro: GPX To Features	Spatial point features
4	IDW interpolation; Project Raster	Elevation raster in the working system
5	Contour; Smooth Line; elevation labels	Labeled contour mapping
6	Hillshade and map layout	Terrain visualization and map sheet
7	Civil 3D: coordinate settings and aerial overlay	Visual check of spatial placement

The final map layout included the title, legend, north arrow, graphic scale, coordinates, data source, and compiler identity. The resulting layout was prepared for printing or export to DWG. Contour and elevation

information was subsequently integrated into Civil 3D to support the existing-ground surface and road-design operations. The project records contain two data-provenance descriptions. The methodological framework identifies DEMNAS obtained through Ina Geoportal, whereas the implementation documents Google Earth Pro coordinates supplemented through GPS Visualizer. Their relationship is not explicitly resolved in those records. The workflow described here follows the documented implementation; the DEMNAS description is retained as a data-provenance qualification requiring confirmation. Mapping validation consisted of checking Civil 3D units and zone settings and displaying the aerial map through Geolocation. No independent surveyed checkpoints or numerical positional and elevation accuracy statistics were reported. The verification procedure therefore provides a spatial-placement check rather than a measured accuracy test.

Geometric calculations and Civil 3D modeling

The mapped terrain was used as the basis for an existing-ground surface in Civil 3D. Horizontal design involved the identification of intersection points, calculation of deflection angles, selection of curve types and radii, and determination of curve lengths. The speed, superelevation, and friction inputs were checked against the PDGJ 2021 criteria adopted for the project. Equation (1) expresses the radius relationship, with the speed in km/h and the radius in metres.

$$R_{\min} = V_D^2 / [127(e + f)] \quad (1)$$

For a full-circle curve, the tangent length, external distance, and circular-arc length were obtained from the radius and deflection angle. The calculations use the relationships in Equations (2) and (3), with the angle expressed in degrees (Kementerian Pekerjaan Umum, 1997).

$$T_c = R \tan(\Delta/2); \quad E_c = T_c \tan(\Delta/4) \quad (2)$$

$$L_c = \pi R \Delta / 180 \quad (3)$$

For an SCS curve, a transition spiral is provided on each side of the circular arc. The procedure calculates the spiral angle, shift, tangent distance, and external distance, followed by the central-arc and total curve lengths. The principal angle and length relationships are given in Equations (4) and (5).

$$\theta_s = 90L_s / (\pi R); \quad L_c = \pi R(\Delta - 2\theta_s) / 180 \quad (4)$$

$$L_{\text{total}} = L_c + 2L_s \quad (5)$$

Superelevation calculations used a normal crossfall of 3% and a selected superelevation of 6%. For FC curves, the design places part of the runoff on the tangent and part on the circular arc. SCS stationing identifies the tangent–spiral, spiral–circle, circle–spiral, and spiral–tangent points. The stationing examples in the results identify the control locations used to define the superelevation transition.

Vertical alignment and earthwork assessment

Vertical calculations begin with the incoming and outgoing grades at each point of vertical intersection (PVI). The algebraic change in grade determines the crest or sag direction, while the length selection compares the applicable K-based length with the practical minimum. The design applies a practical minimum of 0.6 times the design speed, giving 36 m at 60 km/h. Percentage grades are used in Equations (6) and (7).

$$A = g_2 - g_1; \quad L_K = K|A|; \quad L_{\min} = 0.6V_D \quad (6)$$

$$E_v = (g_2 - g_1)L / 800 \quad (7)$$

The selected curves are symmetric about the PVI. Their starting and ending stations are located half the curve length before and after the PVI, respectively. Elevations at the curve ends and at the midpoint are then determined, and the available distance to the next curve is checked for overlap. These operations support the longitudinal profile and its coordination with the horizontal alignment.

$$\text{STA PVC} = \text{STA PVI} - L/2; \quad \text{STA PVT} = \text{STA PVI} + L/2 \quad (8)$$

Civil 3D was also used to prepare longitudinal profiles, cross-sections, and three-dimensional design outputs. Earthwork analysis compared the existing ground with the design surface to calculate cut and fill volumes. The calculation subsequently translated the excess fill requirement into an estimated material mass and number of dump-truck trips using expressly stated density and vehicle-capacity assumptions.

RESULTS AND DISCUSSION

Topographic mapping and spatial integration

ArcGIS Pro processing produced a contour map of the Batu Tambun corridor, with labeled elevations and a hillshade background. Image 2 presents the final contour map, retaining the original labels and symbology. The map

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combines the route, contour information, coordinate grid, and cartographic elements in a single layout, providing the spatial basis used for subsequent geometric design.



Image 2. Contour mapping of the Batu Tambun Road corridor.

Source: original study, Figure 4.12; original map labels retained.

The resulting contours and elevations were integrated into Civil 3D and checked against an aerial background after setting the coordinate system to WGS 1984 UTM Zone 47N. This procedure linked the GIS mapping stage to the road-design environment. These outputs demonstrate the connection between terrain mapping and design modeling. Numerical mapping-error and independent ground-control results were not reported.

The alignment coordinate table contains the starting point A, 24 horizontal intersection points, and the final point B. It lists a cumulative polyline length of 4,839.957 m. This is distinct from the 4,861 m corridor extent stated in the location chapter and the final design length of 4,733.98 m. The study-area extent, coordinate-table total, and final design length are distinct records. Their differences require confirmation because they are not explicitly reconciled in the design documentation.

Horizontal alignment design

The horizontal design contains 24 curves: nine FC curves and 15 SCS curves. Table 4 retains the curve types, angles, selected radii, and lengths stated in the individual curve calculations. FC radii range from 200 to 300 m, while the SCS calculation blocks use radii from 140 to 175 m. All curves were designed using the stated speed of 60 km/h and a selected superelevation of 6%.

Table 4. Reported horizontal-curve parameters

Point	Type	Δ (°)	R (m)	Ls (m)	Lc (m)	Total length (m)
PI1	FC	10.36	200	—	36.163	36.163
PI2	FC	14.88	250	—	64.926	64.926
PI3	FC	15.30	250	—	66.759	66.759
PI4	SCS	31.78	150	35	48.18	118.18
PI5	FC	12.42	200	—	43.354	43.354
PI6	FC	18.08	200	—	63.111	63.111
PI7	SCS	45.31	150	35	83.60	153.60
PI8	SCS	59.38	140*	35	110.07	180.07
PI9	FC	13.85	200	—	48.346	48.346
PI10	SCS	33.28	140	35	46.30	116.30
PI11	SCS	77.60	140	35	154.59	224.59
PI12	SCS	37.87	175	34*	81.65	149.65
PI13	SCS	20.29	140	35	14.56	84.56
PI14	SCS	23.32	150	35	26.03	96.03
PI15	SCS	47.77	140	35	81.71	151.71
PI16	SCS	66.46	140	35	127.37	197.37
PI17	SCS	21.05	140	35	16.42	86.42
PI18	SCS	23.38	150	35	26.19	96.19
PI19	SCS	21.70	150*	35	21.79	91.79
PI20	SCS	19.94	150	35	17.19	87.19
PI21	FC	11.42	200	—	39.863	39.863
PI22	FC	10.49	200	—	36.617	36.617
PI23	FC	6.69	300	—	35.029	35.029
PI24	SCS	33.65	140	35	47.20	117.20

FC: full circle; SCS: spiral–circle–spiral; —: no geometric transition spiral. Numerical precision follows the design records. *PI8 and PI19 radii follow their geometric calculation blocks; their superelevation-input blocks state different radii. PI12 uses the expressly reported 34 m spiral/runoff value; an intermediate expression elsewhere states 35 m.

FC curves occur at PI1, PI2, PI3, PI5, PI6, PI9, PI21, PI22, and PI23; the other 15 points use SCS curves. PI11 has the longest reported SCS length, 224.59 m. PI23 has a 300 m radius and a 35.029 m circular-arc length.

The theoretical criterion reproduced in the design documentation advises against SCS curves with circular portions shorter than 25 m. PI13, PI17, PI19, and PI20 retain SCS classifications despite shorter reported circular portions. These design entries require confirmation; their types and lengths have not been revised.

Representative curve calculations and superelevation stationing

PI1 illustrates the FC calculation. The design adopts a radius of 200 m and a deflection angle of 10.36° , obtaining a tangent length of 18.13 m, an external distance of 0.82 m, and a circular-arc length of 36.163 m. Image 3 presents the plan sketch identifying the deflection at this intersection. The sketch is an alignment illustration, not an additional field measurement.

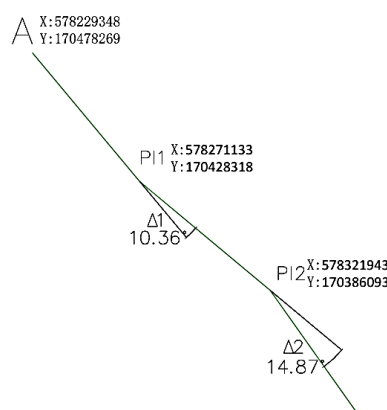


Image 3. Alignment sketch for the PI1 horizontal intersection.

Source: original study, Figure 4.13.

For PI1, the reported Civil 3D stations are TC = 0+046.99 and CT = 0+083.15. The 33 m runoff is divided into 23.10 m on the tangent and 9.90 m on the circular arc. The reported normal and fully superelevated edge-height values are 0.105 m and 0.210 m, respectively. Its calculation reports their difference as 0.105 m and a change rate of approximately 3.18 mm/m. These quantities are retained as reported, without redefining the rotation convention.

PI4 provides an SCS example. Its calculation uses a 150 m radius, a 31.78° deflection angle, and two 35 m spirals. The reported spiral angle is 6.69° , the shift is 0.34 m, the circular section is 48.18 m, and the total curve length is 118.18 m. The corresponding tangent and external distances are 60.28 m and 6.31 m. Table 5 summarizes the final stationing blocks for PI1 and PI4.

Table 5. Representative superelevation stations from the final calculation blocks

Control location	PI1: FC	PI4: SCS
Beginning of runoff	0+023.89	0+421.10 (TS)
Beginning of full superelevation	0+056.89	0+456.10 (SC)
End of full superelevation	0+073.25	0+504.30 (CS)
End of runoff	0+106.25	0+539.30 (ST)

Station values are in metres using chainage notation. The PI4 final stationing block is reproduced; an earlier input line in the source gives a conflicting TS value. TS, SC, CS, and ST denote tangent–spiral, spiral–circle, circle–spiral, and spiral–tangent points.

The two examples show how the calculations connect the selected curve geometry with the longitudinal position of the superelevation transition. The SCS example develops the transition through explicit spiral intervals, while the FC example allocates runoff on both sides of the tangent-to-curve points. These station values form part of the digital design information used to prepare the road model and cross-sections.

Vertical alignment design

The vertical design records list 15 curves, labeled PVI2 through PVI16, comprising seven crest curves and eight sag curves. Fourteen curves use a 36 m design length, while PVI3 uses 40.68 m. Table 6 preserves the reported PVI stations, elevations, algebraic grade changes, classifications, and selected lengths. The stopping sight distance adopted in the calculations is 85 m, with a practical minimum curve length of 36 m.

Table 6. Reported vertical-curve parameters

Point	PVI station	PVI elevation (m)	A (%)	Type	L (m)
PVI2	0+274.19	87.016	-0.15	Crest	36.00
PVI3	0+480.00	89.500	+2.26	Sag	40.68
PVI4	0+751.01	98.917	-2.44	Crest	36.00
PVI5	1+101.07	102.540	-1.72	Crest	36.00
PVI6	1+360.30	100.750	+0.17	Sag	36.00
PVI7	1+650.30	99.250	+1.77	Sag	36.00
PVI8	1+950.00	103.000	-1.92	Crest	36.00
PVI9	2+250.00	101.000	+1.87	Sag	36.00
PVI10	2+500.00	104.000	-1.87	Crest	36.00
PVI11	2+800.00	102.000	-0.66	Crest	36.00
PVI12	3+100.00	98.000	+1.65	Sag	36.00
PVI13	3+410.00	99.000	-1.60	Crest	36.00
PVI14	3+800.00	94.000	+1.96	Sag	36.00
PVI15	4+208.41	96.770	+1.89	Sag	36.00
PVI16	4+490.00	104.000	+0.73*	Sag*	36.00

*The source labels PVI16 as sag and reports $A = +0.73\%$, but its stated incoming/outgoing grades and negative external-offset calculation indicate a contrary classification. The reported category and 36 m length are retained here pending confirmation; the source also contains a conflicting $K \times A$ result for this point.

At PVI2, the incoming and outgoing grades are +1.36% and +1.21%, giving a reported algebraic change of -0.15%. The K-based length is 1.65 m, so the 36 m practical minimum governs. The selected symmetric curve begins at STA 0+256.19 and ends at STA 0+292.19. Its reported midpoint elevation is 87.00925 m, compared with the PVI elevation of 87.016 m.

At PVI3, the grades change from +1.21% to +3.47%, producing $A = +2.26\%$. The sag-curve control $K = 18$ gives 40.68 m, which exceeds the practical minimum and is adopted as the design length. The design gives PVC = 0+459.66 and PVT = 0+500.34, with a midpoint elevation of approximately 89.615 m. This example illustrates the selection of the larger of the two length criteria. The design procedure also checks the space available between consecutive vertical curves. Between PVI2 and PVI3, it reports a PVI separation of 205.81 m, a combined half-

length requirement of 38.34 m, and a free tangent of 167.47 m. It reports no overlap in the subsequent checks. The last vertical curve ends at STA 4+508.00, leaving a reported 225.98 m to the final station at 4+733.98.

Earthwork quantities and material requirements

The comparison between the existing-ground and design surfaces in Civil 3D produced the earthwork quantities summarized in Table 7. The analysis reports a total cut volume of 114,028.72 m³ and a total fill volume of 162,236.77 m³. Because fill exceeds cut, the design requires an additional 48,208.05 m³ of fill material under the calculation assumptions used in the study.

Table 7. Reported earthwork and material-transport quantities

Item	Reported value	Basis
Cut volume	114,028.72 m ³	Civil 3D earthwork output
Fill volume	162,236.77 m ³	Civil 3D earthwork output
Additional fill requirement	48,208.05 m ³	Fill volume minus cut volume
Assumed fill-material bulk density	1.70 t/m ³	Calculation assumption
Estimated additional material mass	81,953.69 t	Volume–density conversion
Dump-truck capacity	10 t	Transport assumption
Estimated number of trips	Approximately 8,196	Reported transport requirement

The volume balance is preserved in Equation (9). The assumed bulk density and truck capacity provide the basis for estimating the additional mass and number of trips. These are planning estimates based on the reported quantities, not observations of completed excavation, embankment construction, or actual haulage.

$$V_{\text{additional}} = 162,236.77 - 114,028.72 = 48,208.05 \text{ m}^3 \quad (9)$$

The volume imbalance indicates that additional material must be supplied to satisfy the fill requirement. The results connect road geometry with the quantity of material to be brought into the corridor, a practical consideration for subsequent construction planning. A detailed cost estimate, pavement structural assessment, and drainage design remain outside the present scope.

Contribution of the integrated workflow

The mapping stage and geometric stage produced different but connected outputs. ArcGIS Pro supplied the contour and elevation information used to describe the terrain, while Civil 3D used the transferred information to develop alignments, profiles, cross-sections, and earthwork quantities. This continuity is consistent with the GIS–Civil 3D emphasis reported by Malik et al. (2019). The Batu Tambun application adds the project-specific combination of a mapped road corridor, 24 horizontal curves, 15 reported vertical curves, and the quantified fill deficit. The contribution also differs from the GIS–PCI road-condition mapping discussed by Siregar et al. (2024) and the accident-prone-area mapping described by Alifianto (2023). Those studies support the assessment of existing conditions or safety risks, whereas this work develops the geometry of a proposed road design. Compared with Marlianti et al. (2023), the scope is narrower because pavement structures and the detailed cost estimate are not included.

The integrated approach supports the preparation and visualization of mapping and design products within a connected workflow. The evidence presented here concerns those outputs; it does not include a controlled comparison of processing time, costs, or surveyed accuracy. The practical contribution is therefore the coordination of spatial information, geometric calculations, and earthwork quantities for Batu Tambun Road. Higher-accuracy field data are still needed to strengthen the design basis. Before construction, the data descriptions, stationing differences, and flagged curve calculations require confirmation through a detailed review and field survey. The reported design quantities have not been replaced by new engineering calculations.

CONCLUSION

The Batu Tambun study produced contour and elevation mapping in ArcGIS Pro and integrated the spatial information into Autodesk Civil 3D for geometric road design. The completed design is reported as 4,733.98 m long, with 24 horizontal curves comprising nine FC and 15 SCS curves. The reported classification identifies 15 vertical curves comprising eight sag and seven crest curves. The design inputs describe a Class III local regency road in the primary network on flat terrain, using a speed of 60 km/h, a 7 m carriageway, and 6% selected superelevation, with reference to PDGJ 2021.

The earthwork analysis reports 114,028.72 m³ of cut and 162,236.77 m³ of fill, leaving a fill deficit of 48,208.05 m³. Under the stated assumptions of a 1.70 t/m³ bulk density and a 10 t truck capacity, this corresponds to 81,953.69 t of additional material and approximately 8,196 trips. The outputs provide a basis for subsequent road-development planning, while the data-provenance and calculation differences identified in the reported material remain subject to confirmation. Further development should use higher-accuracy topographic data, including UAV or Total Station measurements, and verify the geometry through a detailed field survey before construction. Future work should also address pavement structures, drainage, and a detailed cost estimate. Continued integration of ArcGIS Pro and Civil 3D is appropriate within that process, provided that the spatial inputs and engineering calculations are adequately checked.

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