

ANALYSIS AND MAPPING OF PAVEMENT DISTRESS ON THE SIMPANG TANAH ABANG–GALANG–SERDANG BEDAGAI BOUNDARY ROAD, DELI SERDANG

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Abstract

The 11.45-km Simpang Tanah Abang–Galang–Serdang Bedagai Boundary Road, a provincial collector supporting the Trans-Sumatra Highway network, has experienced pavement deterioration. This study identified distress types, assessed road conditions using the Pavement Condition Index (Indeks Kondisi Perkerasan, IKP) and Surface Distress Index (SDI), determined treatments, and mapped conditions and treatment priorities. The survey covered 458 IKP segments at 50-m intervals and 230 SDI segments at 100-m intervals. A total of 843 distress locations were identified across 10 types, dominated by potholes (49.0%) and alligator cracking (20.6%). In the right lane, Poor was the predominant IKP category among distressed segments, comprising 43 segments (18.8%), whereas Fair predominated under SDI (40.9%). In the left lane, the IKP Good category comprised 151 segments, including 120 without distress, while Good predominated under SDI (68.7%). IKP was more sensitive to variations in distress type and severity. ArcGIS mapping showed a concentration of severe distress in the right lane. Reconstruction and structural improvement were prioritized in the right lane, whereas the left lane primarily required routine and periodic maintenance.

Keywords: *ArcGIS; IKP; pavement distress; SDI; treatment priorities.*

INTRODUCTION

Roads play an important role in supporting mobility, the distribution of goods and services, and regional development. Road network quality determines the efficiency of interregional connections, while pavement distress can reduce driving comfort and increase accident risks if it is not addressed promptly (Putri, 2024; Muzki, 2024). Road condition assessments are therefore needed to ensure that maintenance decisions are based on systematically identified pavement conditions. The Simpang Tanah Abang–Galang–Serdang Bedagai Boundary Road is a provincial road connecting Deli Serdang Regency and Serdang Bedagai Regency. It supports the Trans-Sumatra Highway network toward Tebing Tinggi and other areas. Its connecting function, together with community activities along the corridor, makes road serviceability an important concern.

Markets, schools, a police station, places of worship, restaurants, and other public facilities are located along the study road. In addition to serving community activities, the road carries vehicles transporting quarried materials (galian C) from the area around the Ular River. Field observations identified potholes, alligator cracking, raveling, and rutting. During rainfall, standing water conceals some potholes, increasing risks for road users, particularly motorcyclists. Community-funded temporary repairs using fill material have been undertaken, but these measures have not been supported by detailed data on distress types, locations, and severity. With limited resources and funding, quantitative assessment is needed to distinguish segments requiring maintenance from those needing more intensive repairs. Mapping is also necessary so that road condition information can be linked to specific locations rather than presented solely as numerical values (Ersad, 2021). This study used the Pavement Condition Index, referred to by its Indonesian abbreviation IKP, as the primary assessment method and SDI as the comparison method. The results were integrated with a Geographic Information System (GIS) to show the distribution of distress and pavement conditions. The objectives were to identify distress types, determine road conditions using both methods,

select treatments, and map conditions and treatment priorities along the Simpang Tanah Abang–Galang–Serdang Bedagai Boundary Road.

LITERATURE REVIEW

Previous studies and the focus of the present study

Pavement condition assessment combined with GIS has been applied to various roads. Rahmayanti et al. (2024) identified and mapped distress on Kadir Road in Karang Anyar–Gandus using SDI. Their study identified Good, Fair, Slightly Damaged, and Severely Damaged conditions and recommended routine maintenance based on the mean SDI. Santya et al. (2024) assessed the Banda–Nyanglan road in Klungkung Regency and found that Fair was the predominant condition, accounting for 56%. They recommended routine and periodic maintenance according to the condition of each segment. Perangin-Angin (2025) applied IKP assessment and mapping to primary collector roads in Sunggal District, Deli Serdang Regency. The study divided the roads into 100-m segments and mapped 362 distress locations. Edge cracking and patching were prominent, and the recommended treatments included resurfacing, patching, and drainage improvements. On Krucil–Tambelang Road in Probolinggo Regency, Putri (2024) used IKP to determine treatments, with reconstruction accounting for the largest share of treatment needs.

Awaliani et al. (2024), Fadila et al. (2023), and Nadia et al. (2025) used the Pavement Condition Index (PCI) and GIS to assess and map distress in Aceh Tamiang. Their results showed that numerical condition information could be supplemented with distress locations to support treatment planning. Iskandar et al. (2022) also integrated PCI with QGIS on Tamalanrea Raya Road in Makassar. Suhayutianlin et al. (2026) used SDI and ArcGIS on the Ijo–Jatijajar road in Kebumen to show the distribution of distress, even though the road was generally in good condition. The present study differs in its combined use of IKP and SDI, with IKP serving as the primary basis for treatment selection. The two methods were compared to examine consistency in the patterns of results and differences in assessment sensitivity. The analysis was then linked to condition mapping and treatment prioritization. Thus, the study provides not only a distress inventory but also an indication of the treatment required for each segment.

Flexible pavement and the Pavement Condition Index

Flexible pavement uses asphalt to bind aggregates, with successive layers receiving traffic loads and distributing them to the underlying layers. Distress may be influenced by repeated vehicle loading, water, subgrade conditions, base and subbase conditions, material quality, construction practices, and drainage. These factors can interact. Identifying distress type, severity, and quantity therefore provides a basis for selecting appropriate treatments (Sukirman, 1999).

IKP is a quantitative indicator of pavement condition ranging from 0 to 100. It is determined through visual surveys of distress type, severity, and density. Higher values indicate better surface conditions. Although IKP can inform treatment decisions, it does not directly measure pavement structural capacity or provide detailed measurements of skid resistance and roughness (Menteri PUPR, 2016). The calculation begins by determining distress density relative to the sample unit area. A deduct value (NP) is obtained from the curve corresponding to the distress type and severity. The maximum corrected deduct value (NPT) is then determined by applying corrections and iteratively adjusting the number of individual NP values greater than 2. IKP is calculated using the following equation (Menteri PUPR, 2016).

$$\text{IKP} = 100 - \text{NPT}_{\max} \quad (1)$$

The IKP condition classes are Good, Satisfactory, Fair, Poor, Very Poor, Serious, and Failed. Table 1 presents the relationship between IKP values and treatment requirements.

Table 1. IKP Ranges and Corresponding Treatments

IKP	Treatment
≥85	Routine maintenance
70-85	Periodic maintenance
55-70	Structural improvement
<55	Reconstruction

Source: Guideline Pd 01-2016-B.

Surface Distress Index and treatment prioritization

SDI assesses road surface conditions using four parameters: the percentage of cracked area, crack width, the number of potholes, and wheel-path rut depth. The assessment proceeds from SDI 1 to SDI 4. The final value is classified as Good, Fair, Slightly Damaged, or Severely Damaged, as shown in Table 2 (Direktorat Jenderal Bina Marga, 2011).

Table 2. Road Condition Classification Based on SDI

SDI value	Condition
< 50	Good
50 – 100	Fair
100 – 150	Slightly Damaged
>150	Severely Damaged

Source: Road Condition Survey Guide, 2011.

In this study, treatment priorities were determined from IKP values. Segments in worse condition were assigned higher priority. This approach guides treatment sequencing when resources are limited, consistent with the emphasis on distress severity in road maintenance prioritization (Nuryaman et al., 2025).

METHOD

Study location, data, and field survey

The study involved direct observation of the flexible pavement surface along the Simpang Tanah Abang–Galang–Serdang Bedagai Boundary Road in Galang District, Deli Serdang Regency, North Sumatra. The surveyed road was 11.45 km long, extending from STA 0+000 to STA 11+450. Figure 1 shows the study location.

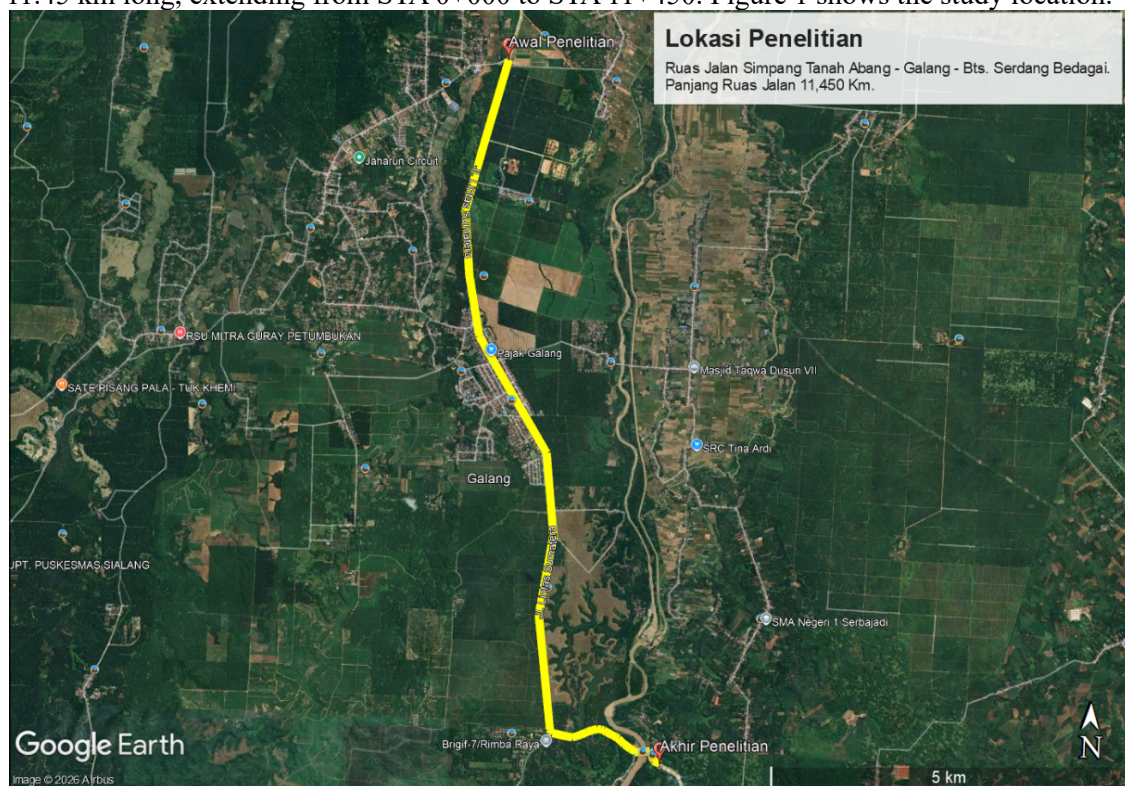


Figure 1. Study Location

Source: Google Earth. Original labels: Awal Penelitian = start of the study road; Akhir Penelitian = end of the study road.

Primary data comprised road length and width, distress dimensions, distress types, severity levels, and the coordinates of distress locations. Secondary data included road function information from the Deli Serdang Regency Spatial Plan (RTRW) and a location map from Google Earth. The equipment consisted of survey forms, stationery, a mobile phone for documentation and coordinate recording, a steel measuring tape, a reel tape measure, a ruler, and measurement aids.

The survey began by dividing the road into 50-m segments, determining stationing (STA), and marking each segment. In each sample unit, distress types and severity levels were identified, dimensions were measured, and the findings were recorded on survey forms. Each instance of distress was documented and its coordinates recorded. The same procedure was repeated for successive segments until the entire road had been inventoried.

The IKP assessment covered 458 segments, while the SDI assessment covered 230 segments at 100-m intervals. Conditions were compared by direction: Galang–Simpang Tanah Abang was designated the right lane, and Simpang

Tanah Abang–Galang the left lane. The assessments followed Guideline Pd 01-2016-B and the 2011 Road Condition Survey Guide No. SMD-03/RCS.

Data processing and road condition mapping

For IKP, the survey data were processed to determine distress density, NP, allowable deduct values, total NP, and maximum NPT. The IKP value for each unit was then calculated to establish its condition class and treatment requirements. For SDI, the analysis considered cracked area, crack width, the number of potholes, and rut depth. The results of the two methods were compared to assess condition patterns in both lanes.

Field coordinates recorded in Avenza Maps were exported in CSV format and imported into ArcGIS using Display XY Data. Longitude was used as the X coordinate and latitude as the Y coordinate, with the WGS 1984 coordinate system. The data were converted to shapefiles, followed by segment processing using Dissolve and Feature to Point according to the study procedure. The attribute table contained STA information, IKP conditions, SDI conditions, and distress categories.

Condition data were selected by attribute and assigned symbols and colors according to the categories of each method. The maps included a title, north arrow, scale, legend, coordinate grid, inset, and data source. The treatment priority bar chart was prepared outside ArcGIS using IKP values for each 50-m segment. It was used alongside the GIS maps to link distress locations to the treatment sequence.

The study was limited to visually observable surface distress. It did not include average daily traffic (ADT) calculations, mechanistic structural analysis, overlay thickness design, engineering economic analysis, or a detailed cost estimate (RAB). Treatment priorities were therefore based on pavement conditions obtained from the IKP assessment.

RESULTS AND DISCUSSION

Road characteristics and distress types

Table 3 presents the general characteristics of the study road. It has flexible pavement, is 7 m wide, and functions as a primary collector. The survey findings were used to assess differences between the lanes and determine treatment requirements based on the evaluation results.

Table 3. General Road Characteristics

No.	Item	Description
1	Road name	Simpang Tanah Abang–Galang–Serdang Bedagai Boundary Road
2	Location	Galang District, Deli Serdang Regency
3	Road length	11.45 km
4	Road type	2/2 TT (two-lane, two-way, undivided)
5	Road width	7 m
7	Pavement type	Flexible pavement
8	Road function	Primary collector
9	Road status	Provincial road

Source: North Sumatra Provincial Development Planning Agency (Bappeda), 2026.

The survey identified 843 distress locations, classified into 10 types under the IKP criteria: potholes (49.0%), alligator cracking (20.6%), patching (10.8%), edge cracking (6.9%), raveling (3.2%), rutting (3.2%), depressions (3.05%), weathering (2.0%), bumps (0.8%), and longitudinal cracking (0.5%). Potholes and alligator cracking were the two most prominent distress types in the field inventory.

IKP assessment results for sample units

The IKP assessment revealed conditions ranging from Good to Failed. In segment 139, STA 6+900–6+950, low-severity alligator cracking covered 1.43 m². A distress density of 0.817% yielded an NP of 9 using the curve in Figure 2. Because only one NP exceeded 2, the total NP was used directly as the maximum NPT. The IKP value was $100 - 9 = 91$, placing the segment in the Good category.

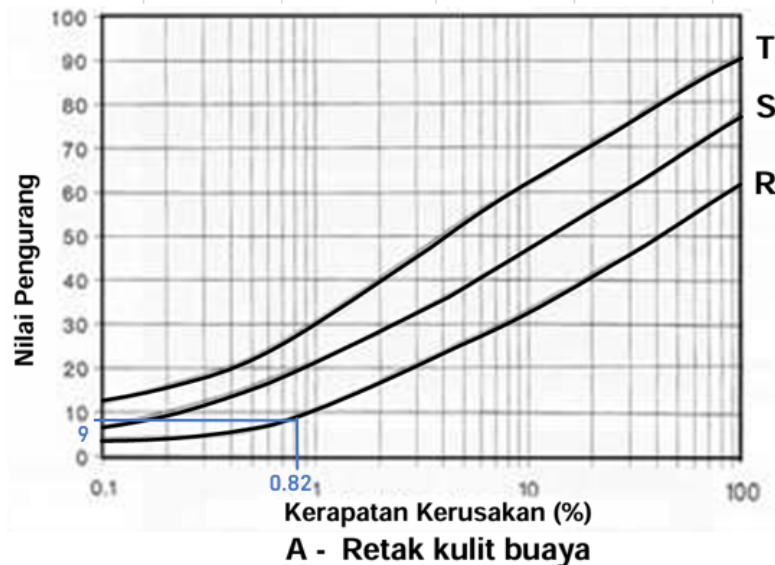
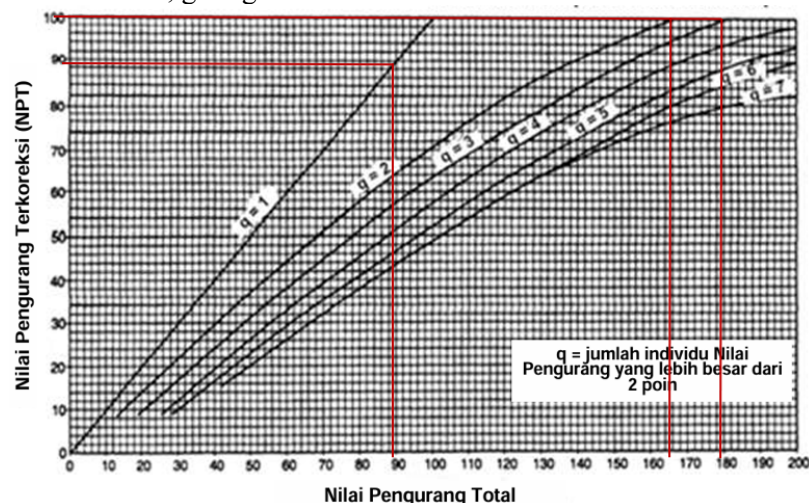


Figure 2. Deduct Value Curve for Alligator Cracking in Segment 139

Source: Analysis of the study results. Original curve labels: R = low, S = medium, and T = high severity; Nilai Pengurang = deduct value; Kerapatan Kerusakan = distress density.

By contrast, segment 326 at STA 4+800–4+850 was classified as Failed. The unit contained high- and medium-severity potholes and high-severity raveling. The assessment yielded a maximum NPT of 100. The NPT curve in Figure 3 shows the correction results, giving an IKP value of $100 - 100 = 0$.



Source: Analysis of the study results. Original axes: Nilai Pengurang Total = total deduct value; Nilai Pengurang Terkoreksi = corrected deduct value; q = number of individual NP values greater than 2.

Other sample units had IKP values of 70 for segment 166, 59 for segment 255, 53 for segment 363, 25 for segment 272, and 14 for segment 230. These values corresponded to Satisfactory, Fair, Poor, Very Poor, and Serious conditions, respectively. This variation shows that a uniform treatment cannot be applied across the entire road corridor.

Summary of IKP results for the right and left lanes

Tables 4 and 5 summarize the assessment of 229 segments in each lane. The distributions include both segments without distress and distressed segments. The overall condition of all segments must therefore be distinguished from the predominant condition category among distressed segments.

Table 4. Summary of IKP Results for the Right Lane

No.	IKP range	Condition class	Segments	Percentage (%)	Treatment
1	≥ 85	Good	72	31.4%	Routine maintenance
2	$70 \leq \text{IKP} < 85$	Satisfactory	26	11.4%	Periodic maintenance
3	$55 \leq \text{IKP} < 70$	Fair	36	15.7%	Structural improvement
4	$40 \leq \text{IKP} < 55$	Poor	43	18.8%	Reconstruction/recycling
5	$25 \leq \text{IKP} < 40$	Very Poor	28	12.2%	Reconstruction/recycling
6	$10 \leq \text{IKP} < 25$	Serious	19	8.3%	Reconstruction/recycling
7	< 10	Failed	5	2.2%	Reconstruction/recycling
Total			229	100%	

Source: Author's analysis.

In the right lane, 72 segments (31.4%) were classified as Good, comprising 51 segments without distress with an IKP of 100 and 21 segments with minor distress. Among distressed segments, Poor was the predominant category, accounting for 43 segments or 18.8% of all right-lane segments. The Poor, Very Poor, Serious, and Failed categories together comprised 95 segments (41.5%), for which reconstruction/recycling was recommended.

Table 5. Summary of IKP Results for the Left Lane

No.	IKP range	Condition class	Segments	Percentage (%)	Treatment
1	≥ 85	Good	151	65.9%	Routine maintenance
2	$70 \leq \text{IKP} < 85$	Satisfactory	22	9.6%	Periodic maintenance
3	$55 \leq \text{IKP} < 70$	Fair	23	10.0%	Structural improvement
4	$40 \leq \text{IKP} < 55$	Poor	16	7.0%	Reconstruction/recycling
5	$25 \leq \text{IKP} < 40$	Very Poor	7	3.1%	Reconstruction/recycling
6	$10 \leq \text{IKP} < 25$	Serious	5	2.2%	Reconstruction/recycling
7	< 10	Failed	5	2.2%	Reconstruction/recycling
Total			229	100%	

Source: Author's analysis.

In the left lane, 151 segments (65.9%) were classified as Good, comprising 120 segments without distress and 31 with minor distress. These 31 segments represented 13.5% of all left-lane segments. The Fair category comprised 23 segments (10.0%), while critical conditions accounted for 33 segments (14.5%). Routine maintenance was therefore the predominant treatment for the left lane, although reconstruction remained necessary for specific critical segments.

Surface Distress Index assessment results

SDI was calculated for 115 segments in each lane. In segment 83, STA 8+200–8+300, the cracked area was 4.49 m² or 1.28%, crack width exceeded 3 mm, one pothole was present, and rut depth was 1–3 cm. The successive SDI values were 5, 10, 25, and 35, resulting in a Good condition classification. Segment 46, STA 4+500–4+600, had an SDI of 85 and was classified as Fair.

In segment 116, STA 0+000–0+100, the total cracked area was 101.82 m² or 29.09%, with crack widths exceeding 3 mm and four potholes. The final SDI of 115 indicated a Slightly Damaged condition. Segment 164, STA 4+800–4+900, contained 15 potholes and had an SDI of 225, indicating a Severely Damaged condition. Tables 6 and 7 summarize the results for all segments.

Table 6. Summary of SDI Results for the Right Lane

No.	SDI range	Condition class	Segments	Percentage (%)
1	< 50	Good	46	40.0%
2	50 – 100	Fair	47	40.9%
3	100 – 150	Slightly Damaged	11	9.6%
4	> 150	Severely Damaged	11	9.6%
Total			115	100%

Source: Author's analysis.

Fair was the predominant condition in the right lane, comprising 47 segments (40.9%), followed by Good with 46 segments (40.0%). The Slightly Damaged and Severely Damaged categories each comprised 11 segments (9.6%). Together, these two damage categories accounted for 22 segments (19.2%), as reported in the study summary.

Table 7. Summary of SDI Results for the Left Lane

No.	SDI range	Condition class	Segments	Percentage (%)
1	< 50	Good	79	68.7%
2	50 – 100	Fair	33	28.7%
3	100 – 150	Slightly Damaged	0	0.0%
4	> 150	Severely Damaged	3	2.6%
Total			115	100%

Source: Author's analysis.

Good was the predominant condition in the left lane, comprising 79 segments (68.7%), followed by Fair with 33 segments (28.7%). No segments were classified as Slightly Damaged, while three segments (2.6%) were Severely Damaged. These findings indicate a more limited need for major treatment in the left lane than in the right lane, although the severely damaged segments still require specific intervention. The SDI and IKP distributions showed consistent patterns: the right lane was in worse condition than the left lane. The differences concerned the classification systems and assessment sensitivity. SDI summarizes four surface parameters, whereas IKP considers variations in distress type, severity, and density within shorter sample units.

Comparison of IKP and SDI results

The two methods showed relatively consistent condition patterns, although their predominant categories differed. In the right lane, Poor was the predominant IKP category among distressed segments, while Fair predominated under SDI. In the left lane, IKP classified most segments as Good, and Good also predominated under SDI. The methods also agreed at STA 4+800–5+000, which was classified as Failed by IKP and Severely Damaged by SDI.

These differences are related to the assessment mechanism of each method. IKP uses NP and NPT based on the combination of distress type, severity, and density at 50-m intervals. SDI uses four distress parameters at 100-m intervals. In the study discussion, IKP was considered more sensitive to localized distress and combinations of distress within a sample unit. This tendency toward more conservative assessment is consistent with the discussion by Sandyna et al. (2022).

Mapping the distribution of distress locations

All coordinates recorded during the survey were mapped using ArcGIS. The overview map in Figure 4 shows the distribution of 843 distress locations along the study corridor. The points were unevenly distributed and tended to cluster in particular segments. Spatial information therefore helped identify sections with a higher density of distress.

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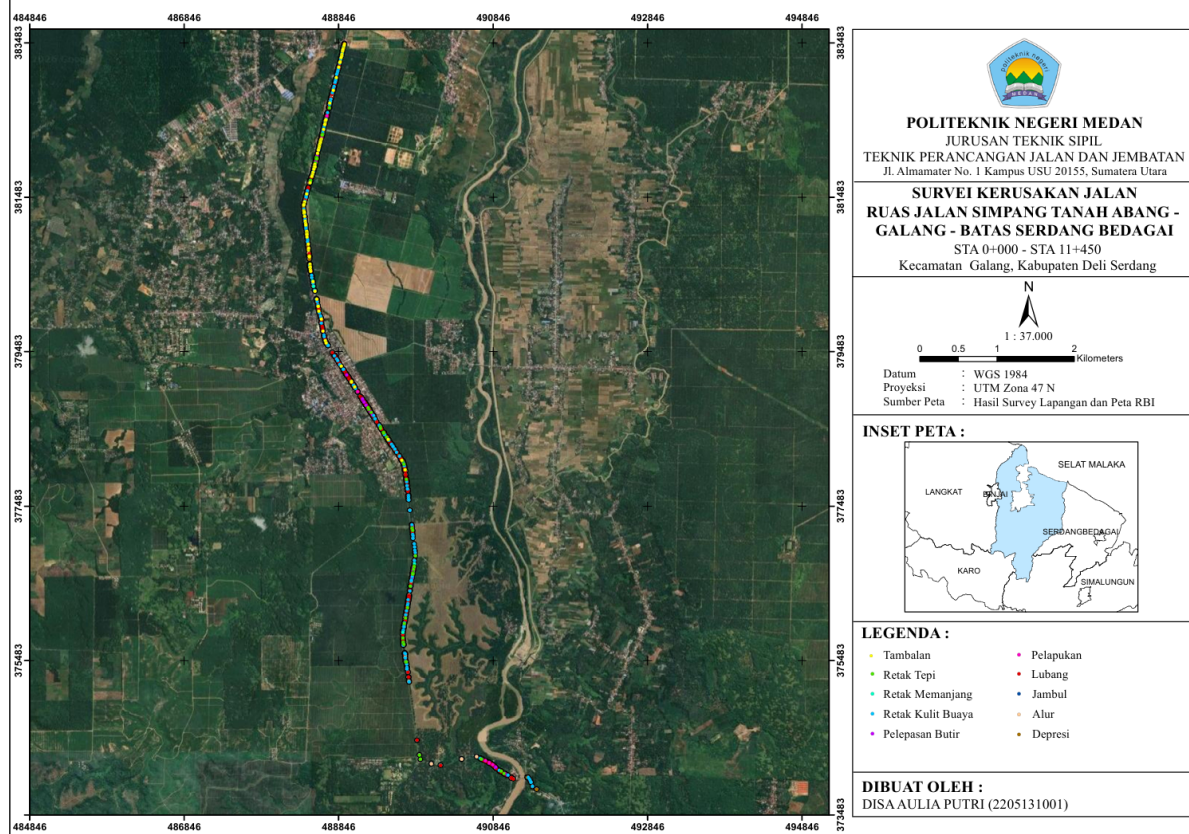


Figure 4. Spatial Distribution of All Distress Locations

Source: ArcGIS. Original legend: Tambalan = patching; Retak Tepi = edge cracking; Retak Memanjang = longitudinal cracking; Retak Kulit Buaya = alligator cracking; Pelepasan Butir = raveling; Pelapukan = weathering; Lubang = potholes; Jambul = bumps; Alur = rutting; Depresi = depressions.

The map of all distress locations provides an overall view, but symbols may overlap where several distress types occur close together. The study therefore also presents separate maps of potholes and alligator cracking so that the distributions of these two predominant distress types can be examined independently.

Distribution of potholes and alligator cracking

Figures 5 and 6 show the two predominant distress types separately. This separation preserves the recorded field coordinates while reducing symbol overlap in the overall map. Potholes and alligator cracking were the main focus because of their prominence in the inventory results.

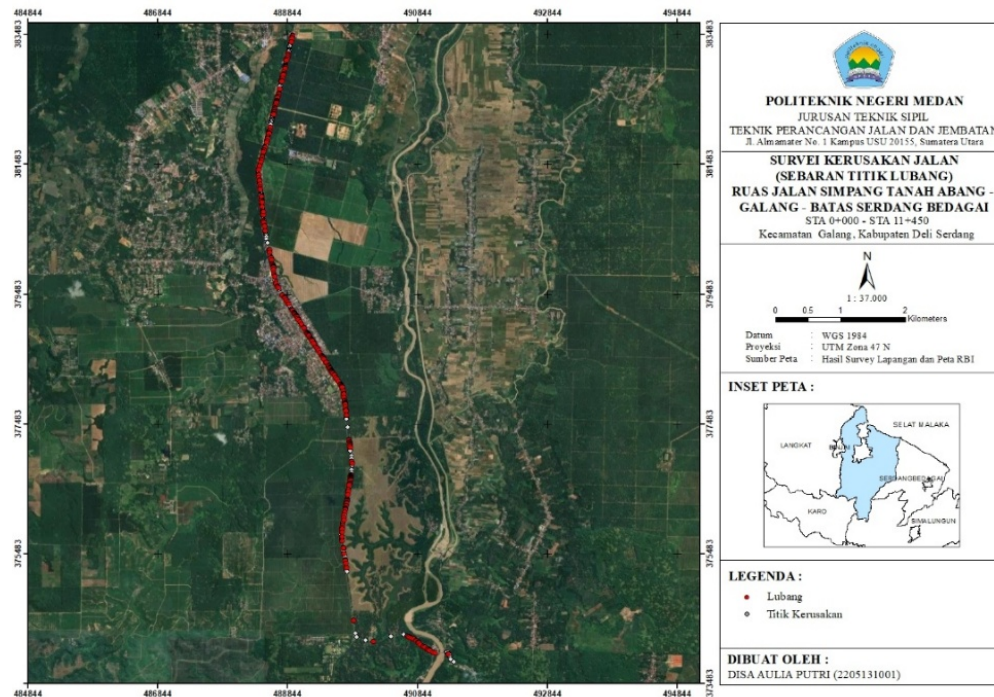


Figure 5. Spatial Distribution of Pothole Locations

Source: ArcGIS. Original legend: Lubang = potholes; Titik Kerusakan = distress locations.

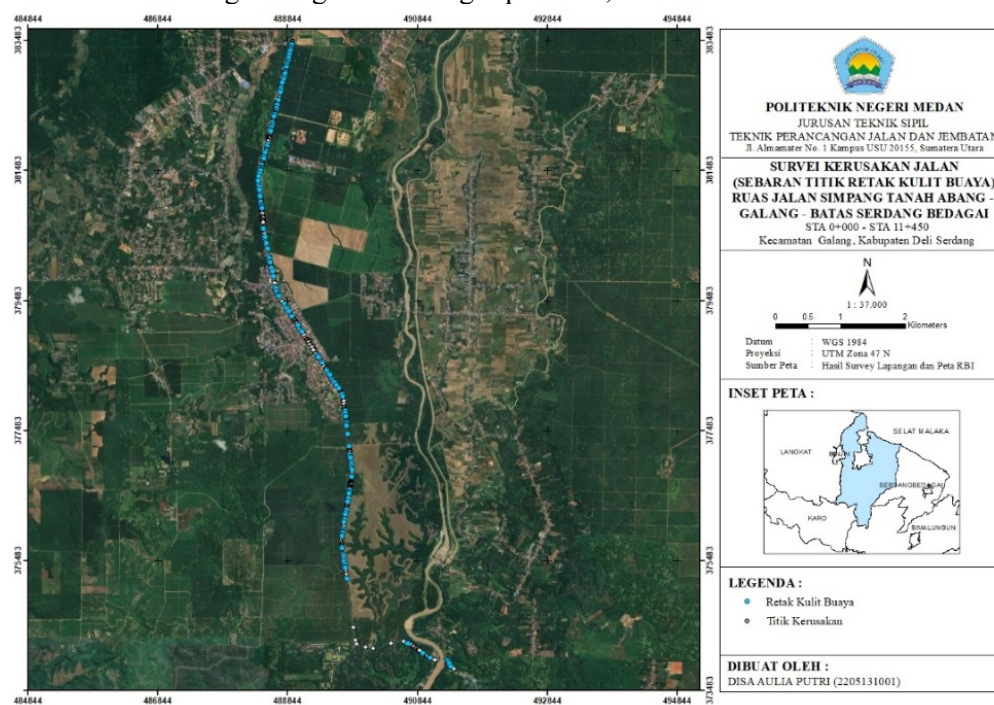


Figure 6. Spatial Distribution of Alligator Cracking Locations

Source: ArcGIS. Original legend: Retak Kulit Buaya = alligator cracking; Titik Kerusakan = distress locations.

Road condition mapping based on IKP and SDI

Condition values for each segment were visualized using colors corresponding to the classifications of each method. Figure 7 uses the seven IKP classes, while Figure 8 uses the four SDI classes. Both maps cover the entire 11.45-km road, allowing variations in condition to be viewed along a single corridor.

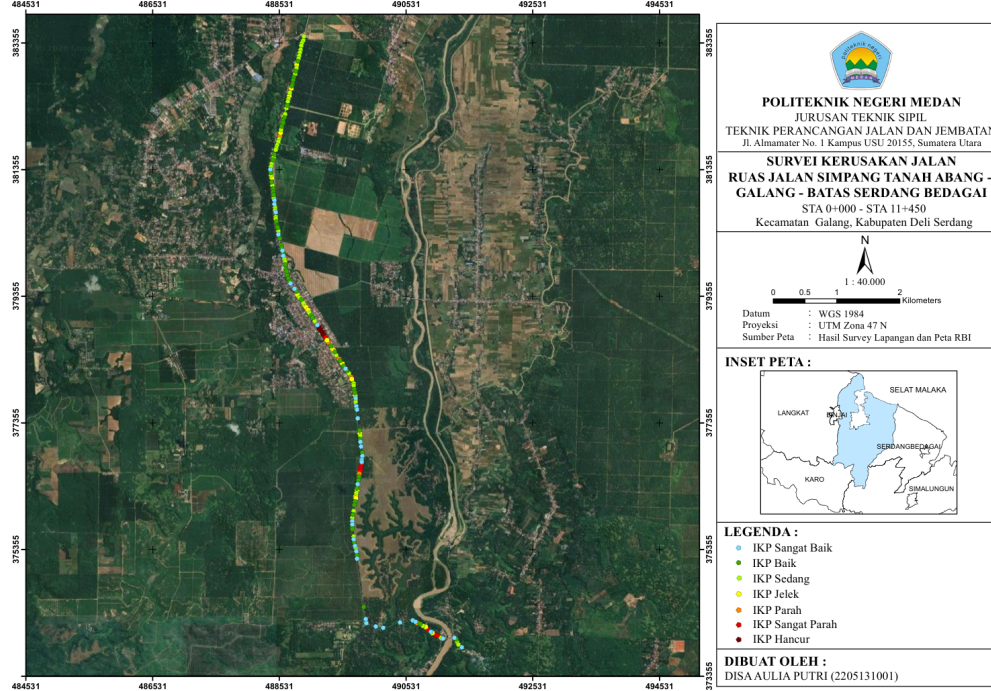


Figure 7. Road Conditions Based on the IKP Method

Source: ArcGIS. Original legend: Sangat Baik = Good; Baik = Satisfactory; Sedang = Fair; Jelek = Poor; Parah = Very Poor; Sangat Parah = Serious; Hancur = Failed.

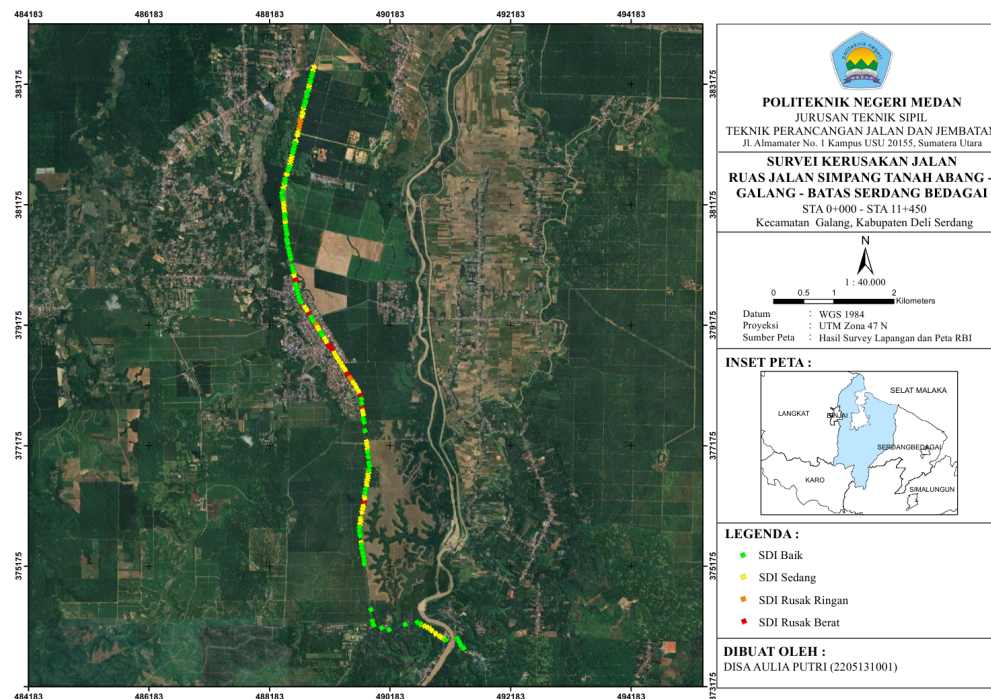


Figure 8. Road Conditions Based on the SDI Method

Source: ArcGIS. Original legend: Baik = Good; Sedang = Fair; Rusak Ringan = Slightly Damaged; Rusak Berat = Severely Damaged.

Treatment priorities and recommendations

Treatment priorities were determined by grouping the IKP results into four types of intervention: reconstruction/recycling, structural improvement, periodic maintenance, and routine maintenance. The bar chart in Figure 9 presents the priorities for each 50-m segment together with photographs of field conditions. It was prepared outside ArcGIS but used alongside the distress distribution and road condition maps.



Figure 9. Road Treatment Priorities

Source: Analysis of the study results. Key: red = reconstruction; orange = structural improvement; yellow = periodic maintenance; green = routine maintenance.

Table 8. Road Treatment Priority Categories

No.	IKP value	Condition	Treatment	Priority level
1	0 – 55	Very Poor	Reconstruction/recycling	Priority 1 (Very High)
2	55 – 70	Poor	Structural improvement	Priority 2 (High)
3	70 – 85	Fair	Periodic maintenance	Priority 3 (Medium)
4	85 – 100	Good	Routine maintenance	Priority 4 (Low)

Source: Guideline Pd 01-2016-B and the author's analysis.

The priority summary in the study conclusions recorded 128 segments (27.9%) under Priority 1, 59 segments (12.9%) under Priority 2, 48 segments (10.8%) under Priority 3, and 223 segments (48.7%) under Priority 4. Reconstruction/recycling was primarily directed toward critical segments, while routine maintenance remained necessary to preserve segments that were still in good condition.

An example of the need for major treatment was identified at STA 4+900–4+950. Structural improvement was indicated at STA 1+500–1+550, periodic maintenance at STA 6+250–6+300, and routine maintenance at STA 10+400–10+450. In the final part of the road, particularly STA 8+500–10+500, many segments fell within the routine maintenance category.

Discussion of treatment requirements and limitations

The difference between the two lanes was thought to be related to the movement patterns of trucks transporting quarried materials. Field observations indicated that fully loaded vehicles used the right lane toward markets or project sites, while vehicles with lighter loads or no load returned via the left lane. Water-saturated loads also caused

continued exposure of the road surface to moisture. Repeated loading combined with water exposure was discussed as a factor accelerating the development of cracks and potholes. Alligator cracking is associated with pavement fatigue caused by repeated loading. Water entering cracks can weaken the underlying layers, while passing vehicles promote material loss and pothole development. This discussion draws on the concepts of flexible pavement and vehicle loading in Sukirman (1999), the Pavement Design Manual (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2024), and the study by Syafrillah et al. (2024). However, this study did not calculate ADT or axle loads, so the magnitude of the traffic effect was not quantified. For IKP values below 55, the study recommended reconstruction/recycling because surface treatment alone was considered inadequate for severe distress. Values of 55–70 indicated structural improvement through an overlay. Values of 70–85 indicated periodic maintenance, while values of at least 85 indicated routine maintenance, including drainage and shoulder cleaning. Overlay thickness design and structural investigation remain subjects for further study.

CONCLUSION

The study of the 11.45-km Simpang Tanah Abang–Galang–Serdang Bedagai Boundary Road identified 843 distress locations across 10 types. Potholes (49.0%) and alligator cracking (20.6%) were predominant. The IKP assessment covered 458 segments, while SDI covered 230 segments. Both methods showed consistent patterns, with the right lane in worse condition than the left lane. IKP was more sensitive to variations in distress type and severity. In the right lane, Poor was the predominant IKP category among distressed segments, accounting for 18.8%, while Fair was the predominant SDI condition at 40.9%. In the left lane, Good predominated in the overall IKP assessment, and Good accounted for 68.7% under SDI. IKP-based recommendations comprised reconstruction/recycling for 128 segments, structural improvement for 59 segments, periodic maintenance for 48 segments, and routine maintenance for 223 segments. The right lane was the main focus for treating critical segments, whereas the left lane primarily required routine maintenance and targeted major repairs.

ArcGIS mapping presented the distribution of distress locations and pavement conditions under both methods. Its integration with the priority bar chart provided a more systematic basis for determining the treatment sequence. Relevant agencies should consider these findings alongside the monitoring of heavy-vehicle loads. Further research should include ADT surveys, vehicle-load analysis, overlay thickness design, Falling Weight Deflectometer (FWD) or Dynamic Cone Penetrometer (DCP) testing, and detailed cost estimation. WebGIS development and the inclusion of additional road sections are also recommended to support updates to road condition information.

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