Desktop Survai – Surface (SCI) / Pavement (PCI) Methodology

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1. Purpose & Scope

This document formalises the current Desktop Survai methodology for computing sealed-road indices (PCI and SCI) and the unsealed-road index (URCI), together with segmentation, inputs, thresholds, and outputs. It mirrors the structure of well-known condition-index frameworks while documenting the practical, field-driven logic implemented in code.

2. Glossary

- **Record:** A single observation frame (typically representing ~10 m of road length) from the Data table.
- **Segment:** A contiguous run of Records grouped under constant context (road ID, sealed/unsealed/material) and bounded by treatment length logic.
- **PCI**: *Pavement* Condition Index (current implementation emphasises structural drivers: rutting, depression/heave, pavement age + visual pavement defects).
- **SCI:** *Surface* Condition Index (current implementation emphasises functional/surface drivers: roughness, surface age + visual surface defects).
- **URCI:** *Unsealed Road* Condition Index.
- **Severity (1–5): 1 = minimal, 5 = intervention level.**
- **Engineering Defaults:** Policy parameters, weights, and lifespans configurable via Engineering Defaults Settings.

3. Data Sources & Required Fields

3.1 Core tables

- **Data –** primary per-record observations (e.g., Road_ID, Chainage, Sealed, Material, Width, Roughness, GNSS, etc.).
- **Defects –** per-record polygonal area measurements and severities by Class.
- **Assessment –** assessed defect severities over ranges (Record_Start, Record_End) by Class.

3.2 Optional/Derived columns (resolved by PRAGMA lookup)

- Urban/Rural flag, Pavement Width, Pavement Date, Surface Date, Unsealed Resheet Date, Material Type.

3.3 Matrices (lookup tables)

- Roughness_Matrix(Score→Value)
- LiDAR_Matrix(Score→RutDepthThreshold)
- Depression_Heave_Matrix(Score→Value)

Matrices provide Score (1–5) thresholds for mapping raw measures to categorical severities/ratings.

4. Segmentation & Treatment Lengths

Segments are built while iterating ordered Data by [Road_ID], [Chainage]. A segment boundary is triggered when any of the following holds:

1. **Road_ID changes (hard break).**
2. **Sealed changes.**
3. **Material changes.**
4. **The distance from Chain_Start reaches the applicable Treatment Length:**
    - Sealed: Urban vs Rural treatment length (from Engineering_Defaults).
    - Unsealed: Unsealed treatment length.
    - End-of-road buffer: if the remaining length to road end is < min(50 m, 20% of Treatment Length), suppress the trigger to avoid tiny tail segments.

Safety check: a GNSS jump >150 m between adjacent records raises an exception to protect data integrity.

5. Input Normalisation & Scoring Primitives

Desktop Survai uses a score-and-accumulate approach on a 1–5 internal scale (with one decimal place of precision), then averages to a segment-level score and finally maps to 1–10 for reporting.

5.1 Age Contribution (Pavement/Surface/Resheet)

- Compute Age (years) = SurveyDate – ObjectDate with multiple accepted date formats.
- If the age dimension is enabled in Engineering Defaults, contribute:

  accumulated_score += Weight * min(1, Age / Life)

  where Life is Pavement_Life, Two_Coat_Life, Asphalt_Life, or Resheet_Life depending on context.
- If the date is missing/invalid and the age dimension is enabled, add half-life: Weight * 0.5 (assumes midway through life).
- Age alone never forces intervention; it cannot directly cause a score of 5.

5.2 Roughness (IRI) Scoring

- For per-record roughness, map the running mean roughness (or the frame roughness where used) through Roughness_Matrix to a Roughness_Score (1–5).
- The matrix is a lookup: the first threshold ≥ rounded roughness defines the score.

5.3 Rutting (LiDAR) Scoring

- For sealed roads in non-wet sections, compute left and right rut depths using per-wheelpath maxima, capped by the matrix's maximum depth to bound outliers.
- Maintain running averages Sum_Left_Rut / nRutCount and Sum_Right_Rut / nRutCount; map the max of the two to a Rut_Score (1–5) via LiDAR_Matrix.
- In wet sections, apply a fixed conservative substitution (left/right += 5 mm equivalent; score ≈ 2) to avoid false positives.

5.4 Depression & Heave Scoring

- A matrix mapping currently keyed off the roughness value path (configurable). If configured independently, pass the appropriate measure. Output is 1–5.

5.5 Visual Defect Area Contribution

For each enabled Defect Class (from Assessment_Matrix.lstPavement, .lstSurface, .lstUnsealed):

1. Per-record areas from Defects are read as absolute m^2 plus a Severity (1–5).
2. Compute a per-record affected-area percentage against the nominal 10 m × Width road patch.
3. Apply area-tier weighting:
    - <10% → ×0.33
    - 10–20% → ×0.66
    - 20% → ×1.00
4. Scale by Severity / 5.
5. Additionally, consume overlapping assessed ranges from Assessment to add linear metres of defect (overlapLength × 10 m × Width × (Severity/5)), preserving any Severity = 5 as a special case.

Severity = 5 (anywhere) returns −1 sentinel from the area routine; this is treated as intervention for the parent index (see §6–§8).

6. Sealed Pavement Index (PCI)

Intent: Reflect structural/pavement health of sealed sections.

Inputs:

- Pavement Age (optional; weight & life from defaults)
- Depression/Heave score (1–5)
- Rutting score (1–5)
- Visual Pavement Defects (weighted area contributions by class)

Computation (per record → segment):

1. Start accumulated_score = 0.
2. If enabled, add Age contribution (never forces 5).
3. If enabled, add Depression/Heave: Weight × (Score/5); if Score = 5 → intervention (segment-level value = 5 for that record's contribution).
4. If enabled, add Rutting: Weight × (Score/5); if Score = 5 → intervention.
5. For each enabled pavement defect class: add Weight × (AffectedArea / (10 × Width)); if any area routine returns −1 → intervention.
6. Convert record aggregate to 1–5 (one decimal place) by:

PCI_record = min(5, round(1 + 4 × accumulated_score / 100, 1))

7. Segment PCI is the arithmetic mean of PCI_record values (1 decimal place) across records in the segment (unless intervention handling below applies).

Intervention handling & threshold-length flag:

- If any record within the segment resolves to 5, the PCI_Threshold_Length accumulates by Capture_Distance × 1.1.
- After a segment closes, if:

  100 × PCI_Threshold_Length / SegmentLength ≥ Intervention_Threshold%

  then flag PCI intervention and set the reported PCI segment score to 5.0.

Reported scales:

- PCI (1.0–5.0) with one decimal place; PCI 1–10 = round(PCI × 2) clamped to [1,10].

7. Sealed Surface Index (SCI)

Intent: Reflect surface/functional condition of sealed sections.

Inputs:

- Surface Age (optional; weight & life: Asphalt vs Two-Coat)
- Roughness score (1–5)
- Visual Surface Defects (weighted area contributions by class)

Computation (per record → segment):

1. accumulated_score = 0.
2. Add Age contribution if enabled (never forces 5).
3. Add Roughness: Weight × (Score/5) (roughness alone does not force 5 in SCI path).
4. For each enabled surface defect class: add Weight × (AffectedArea / (10 × Width)); if any returns −1 → intervention.
5. Convert to 1–5 (one decimal place) via min(5, round(1 + 4 × accumulated_score / 100, 1)).
6. Segment SCI is the mean over records (1 decimal place); apply the same threshold-length rule for any record that hits 5.

Reported scales: SCI (1.0–5.0) with one decimal place, and SCI 1–10 = round(SCI × 2).

8. Unsealed Road Condition Index (URCI)

Inputs:

- Resheet Age (optional)
- Roughness score (1–5)
- Profile score (1–5)
- Gravel Cover score (1–5)
- Visual Unsealed Defects (weighted area contributions by class)

Computation:

1. accumulated_score = 0.
2. Add Resheet Age if enabled (never forces 5).
3. Add Roughness, Profile, Gravel Cover where enabled: Weight × (Score/5); Profile or Gravel Cover = 5 → intervention.
4. Add area contributions for enabled classes; −1 sentinel → intervention.
5. Convert to 1–5 (one decimal place) via min(5, round(1 + 4 × accumulated_score / 100, 1)).
6. Segment URCI is the mean over records (1 decimal place); apply threshold-length intervention rule analogous to PCI/SCI.

Reported scales: URCI (1.0–5.0) with one decimal place, and URCI 1–10.

9. Intervention Thresholding (Segment Level)

For each of PCI, SCI, URCI:

- Maintain a per-segment length counter of records that individually evaluate to 5.0 (using Capture_Distance × 1.1).
- If the percentage of such length over the segment length ≥ Engineering_Defaults.Intervention_Threshold, set the segment's reported score to 5.0 and flag the segment with the corresponding intervention message (de-duplicated text concatenation).

10. Output Artefacts

10.1 Shapefile (Polyline)

- Path: \Shapefiles\Assessed Segment.shp
- Spatial reference: WGS84 (PRJ written alongside SHP).
- Attributes include (abridged): Survey ID, Road ID/Name, Sealed, Material, Asset ID, Chain Start/End, PCI/SCI/URCI (1.0–5.0), PCI/SCI/URCI (1–10).

10.2 Excel (CSV/XLSX)

- Path: \Excel\Assessed PCI_SCI.xlsx
- One row per segment with: segment metadata (IDs, dates, locality, hierarchy), selected inputs (age/roughness/rut/range-based defect summaries), computed indices (1 decimal place), and any commentary flags (e.g., *“Severe rutting”*, *“Surface is old”*).

11. Policy & Configuration

- **Treatment Lengths:** Urban, Rural, Unsealed.
- **Lifespans:** Pavement, Two-Coat, Asphalt, Resheet.
- **Weights:** Age, Roughness, Rutting, Depression/Heave, and per-defect weights in Assessment_Matrix (separate lists for Pavement, Surface, Unsealed).
- **Matrices:** Roughness_Matrix, LiDAR_Matrix, Depression_Heave_Matrix (Score→Threshold semantics).
- **Intervention Threshold:** % of segment length at score 5 required to declare segment-level intervention.

12. Edge Cases & Safeguards

- **GNSS jumps** (>150 m between consecutive records) halt processing (data integrity).
- **Zero-length segments** and **duplicate chainages** are suppressed.
- **Wet sections:** rutting logic switches to an averaged/substituted approach to avoid spurious peaks.
- **Missing dates:** age contributions assume half-life when enabled; never cause intervention on their own.

13. Interpretation Notes

- **Scale meaning:**
  - **1–5**: 1 = best, 5 = **intervention**.
  - **1–10**: display convenience = round((1–5) × 2).
- **Group emphasis:** In the current implementation:
  - **PCI** aggregates *structural* signals (rutting, depression/heave, pavement defects/age).
  - **SCI** aggregates *surface/functional* signals (roughness, surface defects/age).
- **Unsealed** roads bypass PCI/SCI and compute **URCI** instead.

14. Pseudocode (per Record → Segment)

```
for each record in ordered(Data by Road_ID, Chainage):
if boundary_trigger: close_segment()

// Context
sealed := (Data.Sealed == 1)
width := Data.Width (fallback per defaults)

// Running stats
update roughness_mean, rut_left/right (with caps; wet-section substitution)

if sealed:
PCI_record := Assessed_PCI(record)
SCI_record := Assessed_SCI(record)
else:
URCI_record := Assessed_URCI(record)

accumulate per-segment lists and threshold-length if any = 5

end for
close_segment()
```

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15. Validation & QA

- **Matrix sanity:** ensure ascending thresholds for Score 1→5.
- **Weight totals:** review per group so contributions scale sensibly (the 1 + 4×…/100 mapping expects the sum of weighted contributions ≲ 100 under typical conditions).
- **Spot checks:** verify defect area normalisation uses the **10 m × Width** convention consistently.
- **Consistency:** confirm Depression/Heave uses the intended measure path (currently shares the roughness argument).
