Map of the network

1200 km motorways + 600 km main roads

mostly 2X2 lanes,
hence ±7200 km of lanes,
of which ±1500 km were inspected.

Wallonia = southern part of Belgium
Context of presented work

- **Primary roads (managed by “SOFICO”):**
  - Motorways and main roads.

- **Available: surface characteristics**
  - Roughness, skid resistance, rutting.

- **Missing: bearing capacity, residual life**
  - Priorities of maintenance based on surface characteristics only,
  - Need for structural analysis of those roads.
Why do we use indicators?

- Road structure details unknown:
  - Back-calculation for the network is unreliable.
- Easy to compute:
  - Direct from “raw measurement data”.
- Only needs: classification and prioritization.
- Note:
  - Measurement data are available for detailed analysis (when preparing a call for tender).
What the indicators express?

- A **global indicator**
  - expressing residual service life, and
  - allowing a classification of road sections.

- Based upon indicators for:
  1. Bearing capacity.
  2. Bonding between (upper) layers.
  3. Cohesion of (whole) road structure.
  4. Traffic volume (number of vehicles).
  5. Aggressiveness of heavy traffic.
Deflection measurements

• On concrete roads (rigid roads)
  ▪ Falling Weight Deflectometer (FWD)
    ▪ Force: 100kN
    ▪ 1 measurement point every 100m
    ▪ 9 geophones (0, 300mm,...,2400mm)
Deflection measurements

- On bituminous surfaces (semi-rigid roads)
  - Curviameter
  - 13T axle
    - (65kN wheel load)
  - 1 point every 5m
Deflection and Curvature Radius

**Curviameter**
- maximum deflection
- measured radius
- 100 points on curve

**FWD**
- maximum deflection
- computed radius
- “hysteresis” data
Step 1: “homogeneous sections”

- **Curviameter**
  statistical analysis of the maximal deflections ($D_{max}$) (as in a French standard)

Also delivers characteristic deflection ($D_c$) in the homogeneous section: $D_c = D_{max,\text{average}} + 2\sigma$

- **FWD**
  dynamic segmentation by the cumulative sum method (cf. COST 336 of FWD)
Step 2: compute indicators

- Details/definitions: see paper.
- Philosophy:
  - Exploit available knowledge on data interpretation,
  - Extend carefully where necessary: “same” indicator for FWD (rigid) and Curviameter (semi-rigid),
  - Combine “structural indicators” into “reasonable global indicator”, weighing by “traffic indicators”,
  - Check that categorization by global indicator is as good as categorization by back-calculation.
KPI1: bearing capacity

- **FWD**: $T_z = \left(\frac{R_c}{D_{\text{max}}}\right)^{0.5}$
  - $R_c$ to be computed for FWD data
  - $T_z$ low $\sim$ bad bearing capacity
- **Curviometer**: $D_c$
  - $D_c \sim$ life-time
- $T_z \propto D_c$
- Hence: $T_z$ should express bearing capacity of road in reasonable shape.
KPI1: bearing capacity

- **Product “Dmax . Rc”**
  - Large variation in homogeneous section means very bad structural shape of the section.
  - Very high value means critical structural shape.

- **KPI1:**
  - first a selection on \((Dmax \cdot Rc)\)
  - otherwise: \(KPI1 = f(\text{average } Tz)\)
KPI2: layer bonding

- Bad bonding in upper layers may give:
  - Small $R_c$ (Curvimeter), big $D(0)-D(300)$ (FWD)
  - Noise on raw Curvimeter signal:

- KPI2:
  - If large variation in $R_c$ then high KPI2 (bad bonding, $R_c$ both with FWD and Curvimeter)
  - Otherwise compute KPI2 from:
    - difference between $D(0)$ and $D(300)$ (in case of FWD)
    - indicator for noise on raw signal (in case of Curvimeter)
KPI3: cohesion (FWD)

- Load-displacement plot: surface and slope

![](chart.png)

- KPI3:
  - Use $D(0), D(900)$ for “upper part” and $D(900), D(2100)$ for “lower part”
  - Surfaces: all small (KPI3 is good) or all large (KPI3 is bad)
  - Otherwise: count “jumps” for surfaces & slopes, upper & lower part
KPI3: cohesion (Curviameter)

- **E(0)** = difference of these areas under the curve:
  
  (inspired by “energy” surface of FWD)

- **KPI3:**
  
  - Compute in homogeneous section:
    
    - Average Em of E(0), standard deviation $\sigma_M$
    
    - 1st criterion: Em very small (good) or very large (bad)
    
    - Else, 2nd criterion: $\sigma_M$ small (rather good)
      
      or $\sigma_M$ large (rather bad)
KPI4 and KPI5: traffic

- **KPI4**: any type of vehicles
  - daily average *number of vehicles*, as counted
  - rescaled on interval $[0;5]$

- **KPI5**: heavy vehicles only
  - different for rigid and semi-rigid road
  - *aggressiveness* factor w.r.t. standard axle load
  - transfer from % of heavy vehicles to average spectrum of the province (since we don’t have traffic spectrum on each location)
  - rescaled on interval $[0;5]$
Global indicator residual service life

- KPI1 (bearing capacity) is transformed using KPI4 and KPI5 (traffic): $KPI1m$

- Combined indicator

$$CSI = \frac{KPI1m + KPI2 + KPI3}{3}$$

- Global indicator:
  - $CSI > 3$: road is “end of life”, $GI > 4$
  - **Otherwise**: GI gets “cubic effect” of characteristic deflection on expected life time.
GI versus back-calculation

• Back-calculation (as on “project level”):
  ▪ linear-elastic model,
  ▪ on 53 homogeneous sections, 8 road structures.

• Observations:
  ▪ similar categorization of structural health,
  ▪ this back-calculation also has its limits,
  ▪ useful to compare life-time expectance not only with GI but also with Tz, KPI1, KPI2, KPI3.
Conclusions

• these indicators:
  ▪ down to earth, pragmatic approach.

• imperfections but:
  ▪ GI gives a good categorization,
  ▪ checked by back-calculation.

• network level indicators:
  ▪ easy to compute from raw measurement data only,
  ▪ global indicator is used for priority setting.

• detailed data are still available:
  ▪ KPI1 (Tz), KPI2, KPI3: first indication of cause of distress,
  ▪ deflection data for tender preparations for road works.
The Use of Deflection Measurements in Pavement Management of the Primary Road Network of Wallonia, Belgium.

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