EVALUATION OF SPRING LOAD RESTRICTIONS (SLR) EFFECTS ON PAVEMENTS

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Heavy trucks

Truck factor = \[
\frac{2 \times \text{weight}}{\text{Axle weight}} = \frac{16 \times \text{damages}}{\text{Reference axle w.}}
\]

- **2 x weight = 16 x damages**

- **AASHTO:**
  - 1 ESAL = 1 single axle of 8 165 kg
  - = 1 tandem axle of 15 200 kg
  - = 1 tridem axle of 21 800 kg
Trafic evaluation

- 3,500 counting and classification stations
- 10 Weigh-In-Motion (WIM) scales
- ESALS calculated with ASTM E1318
Load Equivalency Factor: $\Delta \text{LEF} = F(\Delta \text{weight})$

- MTQ 70%
- City 17.5%
- MTQ 30%
- City 82.5%

Status quo

Fully loaded

Nominal weight restriction ($\Delta \text{weight}$)
Heavy Traffic during the spring period

- **ESAL per day** \( \approx 60\% \) of summer
  - Average truck \( \approx \) LEF 20\% smaller (SLR of 15\%)
  - Shipments needs about \( \approx 20\% \) less than normal period

- **SLR removal hypothesis**
  - Average truck load same as summer
  - \( \approx 7\% \) less displacements \( \Rightarrow \) **ECONOMY OF THE INDUSTRY**
  - Shipments needs about \( \approx 20\% \) less than normal period

Increase ESALS of 19\% (18 \% inside cities)
If We Remove Spring Load Restrictions (SLR)

=> 19% more ESALS per day
(18% inside cities)
19% more ESALS if we remove SLR
Structural Damages

⇒ Wheelpath Distresses
Damages During Spring Thaw

- 1a-Literature (example from AASHTO)

From all the cases found in literature, spring thaw damages varies from 0.3 to 0.85
Damages During Spring Thaw

1b-Performance monitoring (H10, Fleurimont)

Dp = \frac{\text{cracks occurring during thaw}}{\text{Total cracking}}

Dp = 0.35 to 0.91 (0.7)
A lot of pavement damaging occurs during winter thawing events

- Climatic variability between different years

Ability to raise SLR during each thawing events, including those in winter, would be the ideal of beauty

Winter Weight Premiums does not appear as a very good feature
Falling Weight Deflectometer (FWD)

9 géophones
Structural Damaging (1/N)

Layered Elastic Analysis Softwares

\[ N_1 = K_1(\varepsilon)^{K_2}(E)^{K_3} \]
Unbound Materials Moduli
Rang Saint-Alexis, Saint-Maurice

Date of FWD test

Nov            Jan             Mar            May           Jul             Sep            Nov

200
180
160
140
120
100
80
60
40
20
0

Aggregate base

Silt

Clay

WINTER

THAW

Moduli (MPa)
Structural Indicators

- $\varepsilon_t$: AC elongation (fatigue cracking)
  - Six models from MTQ laboratory
  - Models from Norway, Alaska, Shell, Asphalt Institute
  - Empirical criteria based on SCI$_{20^\circ C}$

- $\varepsilon_v$: rutting by permanent settlements

- PSI: AASHTO-1993 model
  - $SN_1$ corrected at 20$^\circ$C
## Theoretical Simulation of Structural Damages

### Freezing Sensor and Climatic Data
- Temperature, freezing, thawing, (water surface, precipitation, melting snow and ice, state of stress)

### Periodic FWD Testing
- Types of materials, thickness, resilient modulus, fatigue strength

### Layered Elastic Theory
- Strain, structural number, surface curvature index

### Traffic Data
- ESAL number

### Fatigue Law
- Miner's Law: \( D_i = \frac{n_i}{N_i} \)
- life expectancy: \( \frac{1}{D_{\text{mean}}} \)

### Damage

<table>
<thead>
<tr>
<th>Time interval</th>
<th>Climatic and other conditions</th>
<th>Properties of the layers of pavement</th>
<th>Pavement deterioration indicator</th>
<th>N</th>
<th>n</th>
<th>D</th>
<th>RDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>Temperature, freezing, thawing, (water surface, precipitation, melting snow and ice, state of stress)</td>
<td>Types of materials, thickness, resilient modulus, fatigue strength</td>
<td>Strain, structural number, surface curvature index</td>
<td>N = f (indicator)</td>
<td>( n_i ) = ESAL number</td>
<td>( D_i = \frac{n_i}{N_i} )</td>
<td>RDF = ( D_i / D_{\text{mean}} )</td>
</tr>
<tr>
<td>Week 2</td>
<td></td>
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<tr>
<td>Week 3</td>
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<tr>
<td>Week i</td>
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<tr>
<td>Week 52</td>
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</tr>
</tbody>
</table>
Theoretical simulations (damaging)

Normalized and cumulated damages

SLR = 0.85

Week number

Highway 73, Scott-Jonction
Highway 20, Montmagny
Road 161, Saints-Martyrs-Canadiens
Road 155, Saint-Célestin (direction nord)
Road St-Alexis, Saint-Maurice (1993-94)
Road 352, Saint-Narcisse (1993-1994)
Road 159, Sainte-Anne-de-la-Pérade (1993-1994)
Road 361, Saint-Narcisse (1993-1994)
Spring damages $\approx f$ (summer deflection)

- Allow to use deflection inventory in order to extend conclusions for the whole pavement network
  
  (Adjusted values to account for actual traffic conditions)
Dynaflect inventory
ex: national roads

1410 km with DIM between 4 à 5
⇒ $D_p = 0.38$
Weighted average = 0.63

$y = 0.27338x - 0.84637$
$R^2 = 0.61842$
$\varepsilon = 0.15$

Average DIM = 5.07

$DIM = \sqrt{(0.25 \cdot d_{0c} \cdot SCI_{300c})}$
If We Remove Spring Load Restrictions (SLR)

% life reduction = \( Dp \times \Delta \text{ESALS} \)

<table>
<thead>
<tr>
<th>Road Type</th>
<th>% Life Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highways</td>
<td>0.08 (0.37 x 0.19)</td>
</tr>
<tr>
<td>National roads</td>
<td>0.12 (0.63 x 0.19)</td>
</tr>
<tr>
<td>Régional roads</td>
<td>0.14 (0.71 x 0.19)</td>
</tr>
<tr>
<td>Collector roads</td>
<td>0.15 (0.78 x 0.19)</td>
</tr>
<tr>
<td>Municipal roads</td>
<td>0.14 (0.74 x 0.18)</td>
</tr>
</tbody>
</table>

- A typical kilometer of *National Road* cost 10 000$ per year to maintain. The reduced life expectancy of 12% means a minimum annual overcost of 1200 $ per km.

\[ Dp = \text{Damages during SLR period} \]
Exclusion of the km where $\Delta IRI \geq 2$:

- AUT: 3.5%
- NAT: 11.2%
- REG: 21.6%
- COL: 20.1%

Damages not related to heavy vehicles
## Actual maintenance cost of the pavement network

<table>
<thead>
<tr>
<th>Class of road</th>
<th>Cost (k$ / km / year)</th>
<th>Network (km)</th>
<th>Cost (M$ / y)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LCCA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highways</td>
<td>14,5 à 18,1</td>
<td>3 571</td>
<td>51.8</td>
</tr>
<tr>
<td>National</td>
<td>9,2 à 11,9</td>
<td>8 843</td>
<td>85.8</td>
</tr>
<tr>
<td>Regional</td>
<td>6,8 à 9,2</td>
<td>4 535</td>
<td>20.0</td>
</tr>
<tr>
<td>Collector</td>
<td>5,6 à 7,6</td>
<td>6 382</td>
<td>36.9</td>
</tr>
<tr>
<td>Municipal</td>
<td>9,5 à 12,8</td>
<td>32 859</td>
<td>190.0</td>
</tr>
</tbody>
</table>

Municipal : 5,8 based upon values on collector roads

PMS (Pavement Management System)

PMS costs from Jocelyn Beaulieu, ing. Service Orientations stratégiques
Design adjustments

AC thickness (mm)

ESALS (millions)

Δ ≈ 5 mm de B.B.
Δc ≈ 60 €/m²
Δc / c < 1%
If We Remove Spring Load Restrictions (SLR)

MTQ : 24.4

MUNICIPAL : 26.9

TOTAL : 51.3 millions of $

( Highways : 4.2
  National : 11.5
  Regional : 2.9
  Collector : 5.8 )
Sensitivity and reliability within standard deviation of data

- Correlation Dp – DIM: $\sigma = 0.15$
- Costs in PMS: $\sigma = 10\%$
- Above combined

Most probable estimate
COMPARISON

Québec Ministère des Transports
% of weight restricted

Gain or loss (millions of $ per year)

% of weight restricted

- Pavements
- Industry
- Combined
Duration restricted

Gain or loss (millions of $ per year)

Duration of SLR

- Pavements
- Industry
- Combined
Actual SLR are believed to provide at least about 50 millions of $ per year to the public road administrations (+50 > -40)

When comparing with the industry counterpart, the Status quo appear as the optimum homogeneous solution
Heterogeneous approaches

Examples

- **Norway:**
  - SLR: 0 / 12.5 / 25 / 50 % (removed in 1995)
  - Road network divided in three classes of permitted loads all year long: 6 / 8 / 10 metric tons

- **West of North-America (Canada – USA):**
  - One slide per month from November 30th, 1998 to July 1st, 1999.
November 30th, 1998

From McLeod, D.R., D. Palsat and A. Clayton (TAC, 2002)
December 10\textsuperscript{th}, 1998

Winter weight premium (+26\%)
January 14\textsuperscript{th}, 1999
Weight premium (+26\%)
February 11\textsuperscript{th}, 1999
Weight premium (+26%)
Restrictions level 1 (-10%)

From McLeod, D.R., D. Palsat and A. Clayton (TAC, 2002)
March 11th, 1999
Weight premium (+26%)
Restrictions level 1 (-10%)
Restrictions level 2 (-35%)

From McLeod, D.R., D. Palsat and A. Clayton (TAC, 2002)
April 8th, 1999
Restrictions level 1 (-10%)
Restrictions level 2 (-35%)

From McLeod, D.R., D. Palsat and A. Clayton (TAC, 2002)
May 13th, 1999
Restrictions level 1 (-10%)
Restrictions level 2 (-35%)

From McLeod, D.R., D. Palsat and A. Clayton (TAC, 2002)
June 10th, 1999

Restrictions level 1 (-10%)
Restrictions level 2 (-35%)

From McLeod, D.R., D. Palsat and A. Clayton (TAC, 2002)
Heterogeneous approaches

- Some problems remains
  - Enforcement
    - Complicated to adequately practice
    - Actual enforcement scales mostly on highways
    - Increased risk of contravening
  - Needs extensive, network level, monitoring of pavement bearing capacity (deflections)
  - Needs harmonisation of a set of predetermined itineraries
    - Each trucks need to use local roads « before going in » and « after going out » of highways
    - Carefull study needed in order to avoid showing favouritism or being prejudicial to individual interests
  - Increasing restrictions on local roads leads to reduced efficiencies due to unavoidable exceptions (busses, vehicles of public utilities ...)

Increased risk of contravening
Restrictions hétérogènes

- Problèmes subsistants:
  - Gestion et contrôle des charges
    - Plus complexe à appliquer
    - les stations de pesage sont surtout sur les autoroutes
    - Risques accru de contrevenants
  - Nécessité d’une auscultation soutenue de la portance sur tout le réseau
  - Nécessité d’harmoniser les principaux itinéraires
    - Les camions doivent utiliser une route secondaire pour entrer et sortir des autoroutes
    - Étude minutieuse requise pour éviter des injustices entre les différents intérêts individuels des entreprises
  - Des restrictions accrues sur les routes locales veriaient leur efficacité réduite à cause des exceptions inévitables (autobus, véhicules d’utilités publiques, ...)

- Restrictions hétérogènes
CONCLUSION

- Homogeneous restrictions are recommended ...
  until the development of acceptable solutions against the shortcomings of the heterogeneous approach
  - Enforcement more realistic in practice
  - Ensure the same justice for all
  - Status quo appears the optimum homogeneous solution
  - Maintain status quo until further notice
  - Consult all the partners (municipalities and counties, road enforcement services, shippers and industry, other entity concerned).