IMPLEMENTING ADVANCED SKID RESISTANCE MANAGEMENT: RESEARCH, MEASUREMENT, POLICY and ACHIEVEMENT

Peter Cenek

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Presentation Outline

- Overview of Australasian skid resistance management practices
- Current issues facing Australasia
- Lessons learnt from measuring and managing road surface skid resistance over the past decade
- Perceptions of the next decade
## State controlled road networks

### Road length and travel by road type - Australasia - 2003

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Vic</th>
<th>NSW</th>
<th>Qld</th>
<th>NT</th>
<th>WA</th>
<th>SA</th>
<th>Tas</th>
<th>NZ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>National Highway</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length (km)</td>
<td>1 010</td>
<td>3 105</td>
<td>4 186</td>
<td>2 670</td>
<td>4 648</td>
<td>2 749</td>
<td>385</td>
<td>10 790</td>
</tr>
<tr>
<td>Travel ($10^6$veh-km)</td>
<td>3 470</td>
<td>9 296</td>
<td>7 389</td>
<td>561</td>
<td>1 528</td>
<td>2 522</td>
<td>748</td>
<td>18 100</td>
</tr>
<tr>
<td><strong>Rural Arterial</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length (km)</td>
<td>18 100</td>
<td>29 363</td>
<td>27 650</td>
<td>3 972</td>
<td>18 574</td>
<td>8 567</td>
<td>2 514</td>
<td>n/a</td>
</tr>
<tr>
<td>Travel ($10^6$veh-km)</td>
<td>10 060</td>
<td>14 021</td>
<td>7 337</td>
<td>170</td>
<td>4 973</td>
<td>2 648</td>
<td>1 061</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Urban Arterial</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length (km)</td>
<td>3 200</td>
<td>4 235</td>
<td>1 814</td>
<td>150</td>
<td>1 785</td>
<td>911</td>
<td>501</td>
<td>n/a</td>
</tr>
<tr>
<td>Travel ($10^6$veh-km)</td>
<td>24 390</td>
<td>26 351</td>
<td>13 666</td>
<td>534</td>
<td>7 894</td>
<td>5 401</td>
<td>2 656</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Source: Austroads RoadFacts 2005
Victoria

Roading Authority: VicRoads

Skid Resistance Management Plan: Since 1982

Survey Apparatus: SCRIM (modified)

Survey Details: High risk sites in Melbourne metropolitan area and cities with population > 8,000 measured every 3 years.
New South Wales

Roading Authority: Road and Traffic Authority (RTA)
Skid Resistance Management Plan: Since 1982
Survey Apparatus: SCRIM (modified)
Survey Details: 25% of RTA network (≈4,500 km) measured each year.
Roading Authority: Department of Main Roads (QLD)

Skid Resistance Management Plan: *In preparation*

Survey Apparatus: Norsemeter ROAR, variable slip mode, output expressed in terms of IFI.

Survey Details: All state controlled roads with AADT > 10,000 vpd at intervals not exceeding 2 years for higher risk roads and not more than 4 years for remainder.
Northern Territory

Roading Authority: Northern Territory Transport Group

Skid Resistance Management Plan: Systematic testing not conducted.

Survey Apparatus: GripTester has been used in past on urban networks.

Survey Details: British Pendulum Tester used at site specific investigations. Texture surveys over entire network every 4 years with national highway every 2 years.
Western Australia

Roading Authority:
Main Roads (WA)

Skid Resistance Management Plan:
Network level assessment suspended pending further research.

Survey Apparatus:
Norsemeter ROAR, variable slip mode, output expressed in terms of IFI.

Survey Details:
Data collection commenced in 2002 but suspended before the entire network had been surveyed.
South Australia

Roading Authority: DTEI (SA)


Survey Apparatus: GripTester

Survey Details: Biennial to identify low skid resistance. Approximately 110 km surveyed each year, drawn from locations with wet crash history.
Tasmania

Roading Authority: Transport DIER


Survey Apparatus: SCRIM+ (WDM UK Ltd.)

Survey Details: Biennial, total lane length surveyed about 5,000 km. Undertaken in March. IL’s currently under review.
New Zealand

Roading Authority: Transit New Zealand


Survey Apparatus: SCRIM+ (WDM UK Ltd.)

Survey Details: Annually, entire network (10,790 km). Texture, roughness, rutting, and road geometry additionally measured.
Summary of Situation

- SRMP’s driven by legal considerations.
  - i.e. to enable a RA to defend a third party claim
- SRMP’s based on “risk equalisation” across network.
- Targeted surveys favoured. Only New Zealand has adopted 100% surveys.
- No standard procedures for acquiring and reporting skid resistance data.
- PSV and PAFV tests utilised to ensure roading aggregates have satisfactory skid resistance performance.
- No texture depth related IL’s apart from Victoria and New Zealand.
Emerging Issues

- Precision of skid resistance measurements (PSMC driven).
- Harmonisation of skid testers (to generate competitive market).
- 0.78 “Index of SFC” – applied in UK and NZ but not Australia.
- Role of texture in skid resistance management.
- Monitoring programmes and IL’s appropriate to local conditions.
- Relationships between aggregate properties and in-service skid resistance performance.
A Decade of Experience

- T/10 specification implemented in 1997.
- Developed by Transit New Zealand around UK maintenance practice HD 28/94.
- Based on standardising the risk of a wet skid crash across the state highway network.
- Achieved by assigning investigatory skid resistance levels to different site categories, which are related to different friction demands, and target levels of macrotexture.
- Owen and Donbavand “There’s a Fraction, too little Friction.”
A Decade of Experience

- Transit presently spends NZ$4.5 – NZ$5 million per annum on SCRIM related sealing.
- Despite expectation that this level of expenditure would have dropped to $1 million per annum by (2003 - 04 onwards), initiative still regarded as being extremely successful.
Examples of Successes

- Closer collaboration between Transit and NZ Police.
- Level of awareness and practitioners’ understanding raised.
- Safer driving environment for users of the State Highway network.
- Significant decrease in wet-road loss of control crashes despite increased exposure.
- Improved measurement systems and validation procedures.
- Crash - risk model development.
Road Surface Skid Resistance

- Roading Engineer’s Definition:
  “Measure of relative slipperiness”

- Crash Investigator’s Definition:
  “Average coefficient of friction during a skid to stop braking manoeuvre”
Skid Testers Assessed Against LWB
IFI Based Relationship

\[ \mu_{\text{wet}} = \frac{1}{S} \int_{0}^{S} F_{60} e^{\left( \frac{60-S}{S_p} \right)} dS \]

where \( \mu_{\text{wet}} \) = wet road coefficient of longitudinal deceleration

\( F_{60} \) = IFI harmonized wet coefficient of friction for 60 km/h slip speed

\( S_p \) = IFI speed number (km/h)

\( S \) = slip speed (km/h)

\( V_B \) = vehicle speed when locked-wheel braking is initiated
Tread Depth versus Texture Depth
Predicted versus Observed Speed Sensitivities

- Locked Wheel
- IFI - SCRIM
- IFI-SCRIM (Modified)

Wet Locked Wheel Coefficient of Friction

Speed at Brake Application (km/h)
## TNZ Christchurch Trials

<table>
<thead>
<tr>
<th>Test Section</th>
<th>Texture Measurements</th>
<th>Skid Resistance Measurements</th>
<th>IFI Based Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SLP (MPD, mm)</td>
<td>SCRIM (SFC)</td>
<td>British Pendulum (BPN)</td>
</tr>
<tr>
<td>G3 EB</td>
<td>1.19</td>
<td>0.47</td>
<td>63.2</td>
</tr>
<tr>
<td>AC 16</td>
<td>0.42</td>
<td>0.60</td>
<td>65</td>
</tr>
<tr>
<td>AC 16 G</td>
<td>1.34</td>
<td>0.68</td>
<td>85.4</td>
</tr>
<tr>
<td>G6 EB</td>
<td>1.41</td>
<td>0.71</td>
<td>77</td>
</tr>
<tr>
<td>G3 EB</td>
<td>1.91</td>
<td>0.52</td>
<td>63.2</td>
</tr>
</tbody>
</table>

Source: Austroads Technical Report AP-T72/06

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## Design Values of Friction

Austroads sealed road values for stopping sight distance:

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Coefficient of Longitudinal Deceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0.52</td>
</tr>
<tr>
<td>60</td>
<td>0.48</td>
</tr>
<tr>
<td>70</td>
<td>0.45</td>
</tr>
<tr>
<td>80</td>
<td>0.43</td>
</tr>
<tr>
<td>90</td>
<td>0.41</td>
</tr>
<tr>
<td>100</td>
<td>0.39</td>
</tr>
<tr>
<td>110</td>
<td>0.37</td>
</tr>
<tr>
<td>120</td>
<td>0.35</td>
</tr>
<tr>
<td>130</td>
<td>0.32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Speed Change</th>
<th>Percentage Drop in Coefficient of Longitudinal Deceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>50km/h – 130 km/h</td>
<td>36.5%</td>
</tr>
<tr>
<td>70 km/h – 130 km/h</td>
<td>26.7%</td>
</tr>
<tr>
<td>50 km/h – 70 km/h</td>
<td>13.5%</td>
</tr>
</tbody>
</table>
Suggested Minimum Value

SCRIM Coefficient = 0.46

or

British Pendulum Number = 48
and
Texture Depth = 0.45mm MPD
Examples of Successes

- Closer collaboration between Transit and NZ Police.
- Level of awareness and practitioners’ understanding raised.
- Safer driving environment for users of the State Highway network.
- Significant decrease in wet-road loss of control crashes despite increased exposure.
- Improved measurement systems and validation procedures.
- Crash risk model development.
Guidelines for the Management of Road Surface Skid Resistance
Examples of Successes

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Network Texture

Rural all surfaces; Urban only chip seal surfaces

Transit SOI Target < 2.0%

Source: 2007 TNZ State Highway Pavement Condition Report

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Network Skid Resistance

Percentage of network with SFC below threshold or investigatory level

Source: 2007 TNZ State Highway Pavement Condition Report

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Examples of Successes

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Crash Reduction

- Matched Pair Analysis:
  - 95% confidence interval for crash reduction per 0.1 increase in SC:
    - (1.2, 1.7) ... 1995 and 1998 comparison
    - (1.1, 1.8) ... 1995 and 1999 comparison

- Site Specific:
  - SH2, North of Wellington, 98 m radius curve
  - Black spot: 60 personal injury crashes/year
  - 1-2 personal injury crashes/year after application of calcined bauxite
Examples of Successes

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International Friction Index

Distance (m)

International Friction Index, F60

International Friction Index, Sp

SCRiM
GripTester
Norsemometer - 20% slip

surfacing changes

Sp

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Cornering

Wear of measuring tyre
(0.06GN variation)

A = 65 mm (fixed)
125.15 mm ≤ B ≤ 130 mm
(varies according to tyre wear)
Temperature Corrected BPN Variation

Temperature Corrected BPN

- **Oliver's Correction**
- **Road Note 27 Correction**
- **Uncorrected**

Air = 14°C, Road = 16°C

Air = 23°C, Road = 38°C

Time:

07:12 09:36 12:00 14:24 16:48 19:12

BPN:

60 65 70 75 80 85 90

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Spectra Based Validation

- Enabled almost perfect agreement between SCRIM S5 & S10 texture measurements
Examples of Successes

- Closer collaboration between Transit and NZ Police.
- Level of awareness and practitioners’ understanding raised.
- Safer driving environment for users of the State Highway network.
- Significant decrease in wet-road loss of control crashes despite increased exposure.
- Improved measurement systems and validation procedures.
- Crash risk model development.
Derivation of Crash Prediction Model

An attempt to relate road crash rates to:

- Road Condition
- Road Geometry
- Carriageway Characteristics
Main Dataset: SCRIM+

- **Road Geometry**
  - Horizontal Curvature  \( m \)  10m intervals
  - Gradient  \( % \)  10m intervals
  - Cross-fall  \( % \)  10m intervals

- **Road Condition**
  - Lane Roughness  IRI  m/km  20m intervals
  - Rut Depth  mm  20m intervals
  - Texture Depth  mm MPD  10m intervals
  - Skid Resistance  SCRIM Coeff.  10m intervals

*One million data points on each side of the road for each year!*
Expected crash rate \((10^8 \text{ vkt}) = a \cdot e^L\)

Where:

- \(a = \frac{10^{10}}{365}\)
- \(L = \text{weighted sum of values of the following characteristics:}\)
  - year
  - TNZ administration region
  - urban/rural classification
  - T/10 skid-site category
  - skid resistance (SCRIM Coefficient - 0.5)
  - \(\log_{10}(\text{horizontal curvature})\)
  - \(\log_{10}(\text{ADT})\)
  - absolute gradient
  - \(\log_{10}(\text{IRI})\)
## EBOP SMS

<table>
<thead>
<tr>
<th>Source of Crash Numbers</th>
<th>Annual Average Mid Block Crashes</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SH2 RS 194/0-10km</td>
<td>SH30 RS232/0-11km</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All Injury</td>
<td>Wet Injury</td>
<td>All Injury</td>
<td>Wet Injury</td>
<td></td>
</tr>
<tr>
<td>CL Model</td>
<td>2.35</td>
<td>0.39</td>
<td>1.94</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>CAS (2001-2005)</td>
<td>3</td>
<td>0</td>
<td>1.8</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>
Crash Rate versus SCRIM Coefficient

- **all crashes**
- **selected crashes**
- **wet road crashes**
- **selected wet road crashes**

Crash rate (per 10^8 vehicle-km) vs. Scrim coefficient.
### Effect of Skid Resistance: Reduction in Crashes per $10^8$ v-km

<table>
<thead>
<tr>
<th>Change in SCRIM SFC</th>
<th>All Crashes</th>
<th>Wet Road Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>Actual</td>
</tr>
<tr>
<td>0.35 to 0.45</td>
<td>20%</td>
<td>6.4</td>
</tr>
<tr>
<td>0.55 to 0.65</td>
<td>20%</td>
<td>4.1</td>
</tr>
</tbody>
</table>
Effect of Texture

- Increase in texture depth from 0.5 mm to 3.0 mm MPD reduces crash risk from 18.8 to 17.6 of all injury crashes per 108 vehicle-km.

This corresponds to a 7% reduction in crash rate!
Model Uses

- Sufficiently robust for following applications:
  - Improved understanding of factors affecting crash risk and their relative importance.
  - Improved road asset management as the effect of changes to levels of service/performance standards on crash numbers can be quantified.
  - Proactive identification of black spots and to a lesser extent white spots.
  - Policy evaluation.
Main Lessons Learnt

- The need for reliable, accessible, high quality data.
- Significant research effort.
- Environment of openness.
Illustrative Example – Crash Risk Assessment of Horizontal Curves

- 1/3 of all rural SH crashes occur on curves
  - 46% of these are on wet roads
- Equates to approximately 5,700 reported crashes in last 5 years
  - (2000-2004)
- Majority occur on moderate curves
  - (250 to 500m radius)
Influence on Crash Rate – Curvature
Two Candidate Approaches

- Revise T/10 IL’s to achieve more constant risk
- Risk ranking of curves
Possible Revision to T/10

<table>
<thead>
<tr>
<th>Curve Radius (m)</th>
<th>SCRIM SFC</th>
<th>Existing T/10</th>
<th>Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 250</td>
<td>0.5</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>251 - 450</td>
<td>0.4</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>451 - 700</td>
<td>0.4</td>
<td>0.45</td>
<td></td>
</tr>
</tbody>
</table>

- Existing T/10
- Modification to T/10
- ESC=0.7, Calcined Bauxite
Risk Ranking of Curves

- High approach speed exceeds curve speed by $\geq 15$ km/h
- Low approach speed exceeds curve speed by $< 5$ km/h
- Medium all remaining curves
- High (+DG) downhill gradient $\geq 5\%$ over a length of at least 100m prior to curve
- High (LSA) low approach speed ($< 70$ km/h)
Curve Analysis – Speed Definitions

- Approach speed = the calculated speed over 500m preceding a curve in the direction of travel.
- Curve speed = the calculated speed of the tightest 30m (lowest radius) within the curve length.
Curve Analysis – Confirmation

- State Highways investigated:
  - SH1N RS 607 to RS 744
  - SH25A RS 21
  - SH27 RS 16- RS 46 & RS 74 to RS 83
  - SH29 RS 21
- Total No of Curves: 400
- High risk curves = 3.6 crashes/curve
- Medium and low risk curves = 2.2 crashes/curve
## BPT Measurements on Selected Curves

<table>
<thead>
<tr>
<th>Corner</th>
<th>Turning</th>
<th>Radius (m)</th>
<th>BPN Wheelpath Ratio (Outside / Inside)</th>
<th>BPN Ratio (Longitudinal / Radial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Left turn</td>
<td>210</td>
<td>1.05</td>
<td>1.04</td>
</tr>
<tr>
<td>4</td>
<td>Left turn</td>
<td>80</td>
<td>1.02</td>
<td>1.10</td>
</tr>
<tr>
<td>5</td>
<td>Left turn</td>
<td>40</td>
<td>1.09</td>
<td>1.05</td>
</tr>
<tr>
<td>8</td>
<td>Right turn</td>
<td>170</td>
<td>1.03</td>
<td>1.08</td>
</tr>
<tr>
<td>6</td>
<td>Right turn</td>
<td>120</td>
<td>1.06</td>
<td>1.04</td>
</tr>
<tr>
<td>3</td>
<td>Right turn</td>
<td>40</td>
<td>1.04</td>
<td>1.15</td>
</tr>
<tr>
<td>Average all corners:</td>
<td></td>
<td></td>
<td>1.05</td>
<td>1.07</td>
</tr>
</tbody>
</table>
Perceptions of the Next Decade

- Increasing role of road surface texture.
- Recycling or rejuvenation of existing road surfaces.
- Systems approach to road safety management.
- Need for adaptive policies to deal with climate change.
Tread Deformation and Contact Pressure

Grade 2 Chipseal

Grade 6 Chipseal

Texture Profile

Tyre Tread

Void Area
Perceptions of the Next Decade

- Increasing role of road surface texture.
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- Need for adaptive policies to deal with climate change.
High Pressure Water Blasting

Before Treatment

After Treatment

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High Pressure Water Blasting: BPT Number versus Hours of Polishing (continuous line = after water blasting, dashed line = before water blasting)

- Pound Road (crushed)
- Pound Road (peagravel)
- Hastings Quarry (crushed)
- Hastings Quarry (peagravel)

Time of Polishing (Hours)

BPT Number

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Perceptions of the Next Decade

- Increasing role of road surface texture.
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- Need for adaptive policies to deal with climate change.
Electronic Safety Systems

IVIS = In-Vehicle Information Systems
ADAS = Advanced Driver Assistance Systems

Source: friction.vtt.fi/friction.presentation.pdf

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### Intelligent Tyre – APOLLO Project

#### Vehicle dynamics
- Forces/torques
- Friction parameter
- Speed, slip
- Maximum contact force
- Detecting aquaplaning

#### Tyre
- Pressure
- Temperature
- Tread water
- Damage, stress
- Tyre type
- Age
- Logistic parameters

#### Road
- Texture of road surface
- Type of road: concrete, asphalt
- Road condition: dry, wet, icy, snowy

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Source: virtual.vtt.fi/apollo/objectives/project_presentation.pdf

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Perceptions of the Next Decade

- Increasing role of road surface texture.
- Recycling or rejuvenation of existing road surfaces.
- Systems approach to road safety management.
- Need for adaptive policies to deal with climate change.
Thank You