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

Peter Cenek

peter.cenek@opus.co.nz

OPUS Central Laboratories

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

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

Source: Austroads RoadFacts 2005

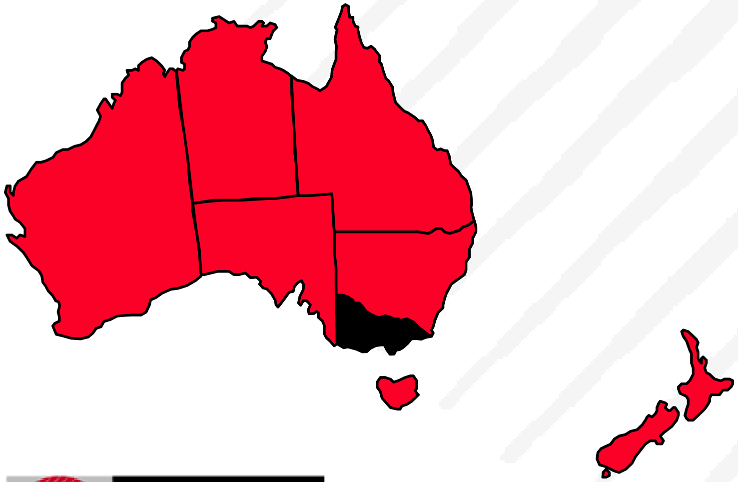
Victoria

Roading Authority: VicRoads

Skid Resistance Management Plan: Since 1982

Survey Apparatus: SCRIM (modified)

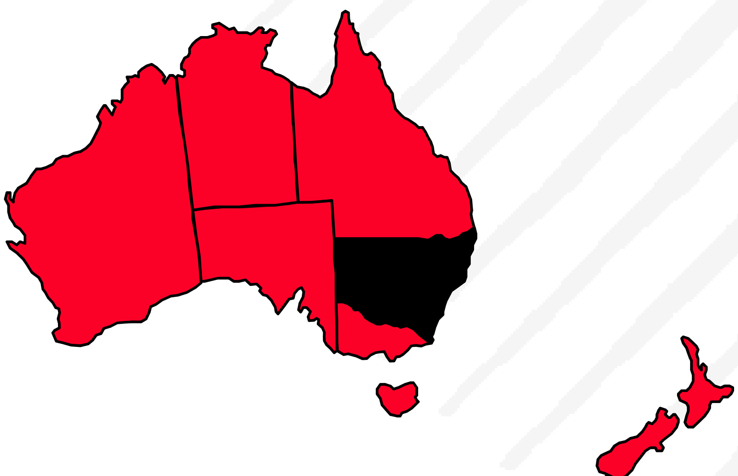
Survey Details: High risk sites in Melbourne metropolitan area and cities with population > 8,000 measured every 3 years.



OPUS Central Laboratories

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.



OPUS Central Laboratories

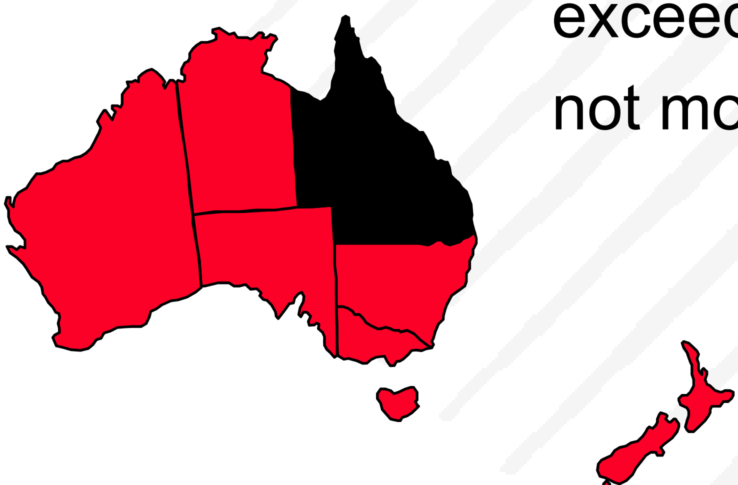
Queensland

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.



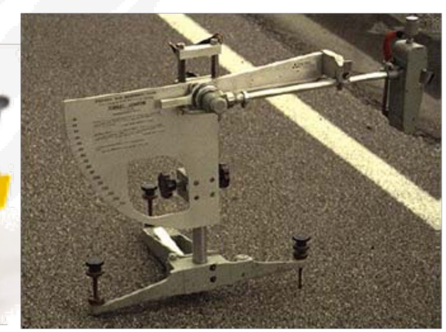
Northern Territory

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.



OPUS Central Laboratories

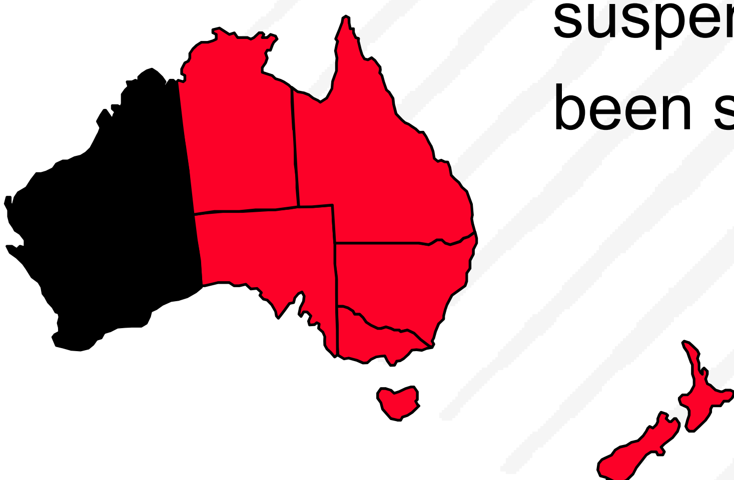
Western Australia

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.



OPUS Central Laboratories

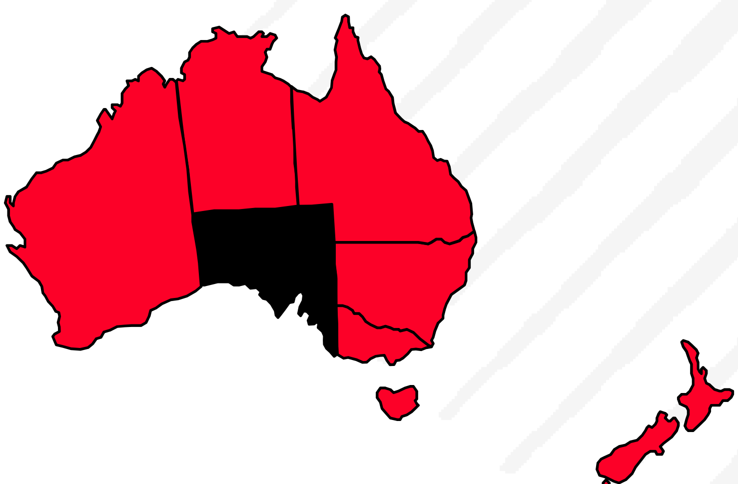
South Australia

Roading Authority: DTEI (SA)

Skid Resistance Management Plan: *In preparation.*

Survey Apparatus: GripTester

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



OPUS Central Laboratories

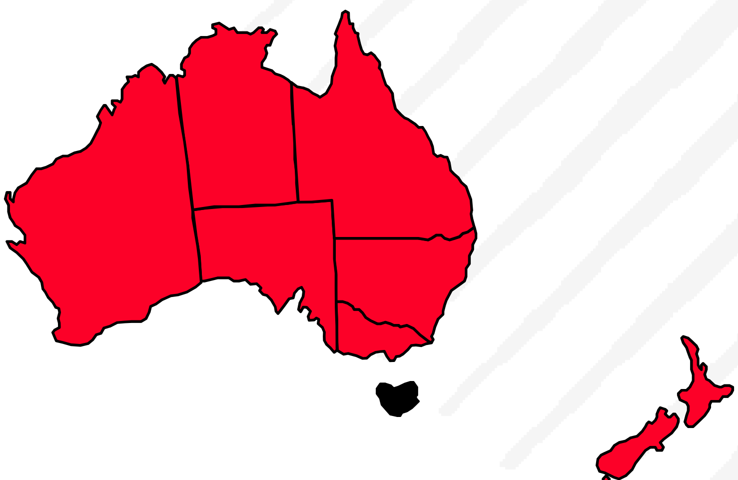
Tasmania

Roading Authority: Transport DIER

Skid Resistance Management Plan: *In preparation.*

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.



OPUS Central Laboratories

New Zealand

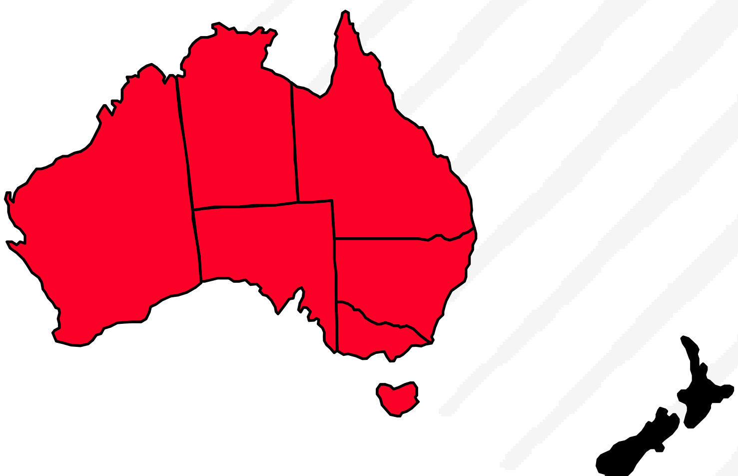
Roading Authority: Transit New Zealand

Skid Resistance Management Plan: Since 1997.

Survey Apparatus: SCRIM+ (WDM UK Ltd.)

Survey Details: Annually, entire network (10,790 km).

Texture, roughness, rutting, and road geometry additionally measured.



OPUS Central Laboratories

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.
- A robust process for prioritising sites for treatment.
- 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

OPUS Central Laboratories

IFI Based Relationship

$$\mu_{wet} = \frac{1}{S}\int_0^S F_{60}\, e^{\left(\frac{60-S}{S_p}\right)} dS$$

$$= \frac{\left[-S_p F_{60}\, e^{\left(\frac{60-S}{S_p}\right)}\right]_{S=0}^{S=V_B}}{V_B}$$

where μ_{wet} = wet road coefficient of longitudinal deceleration

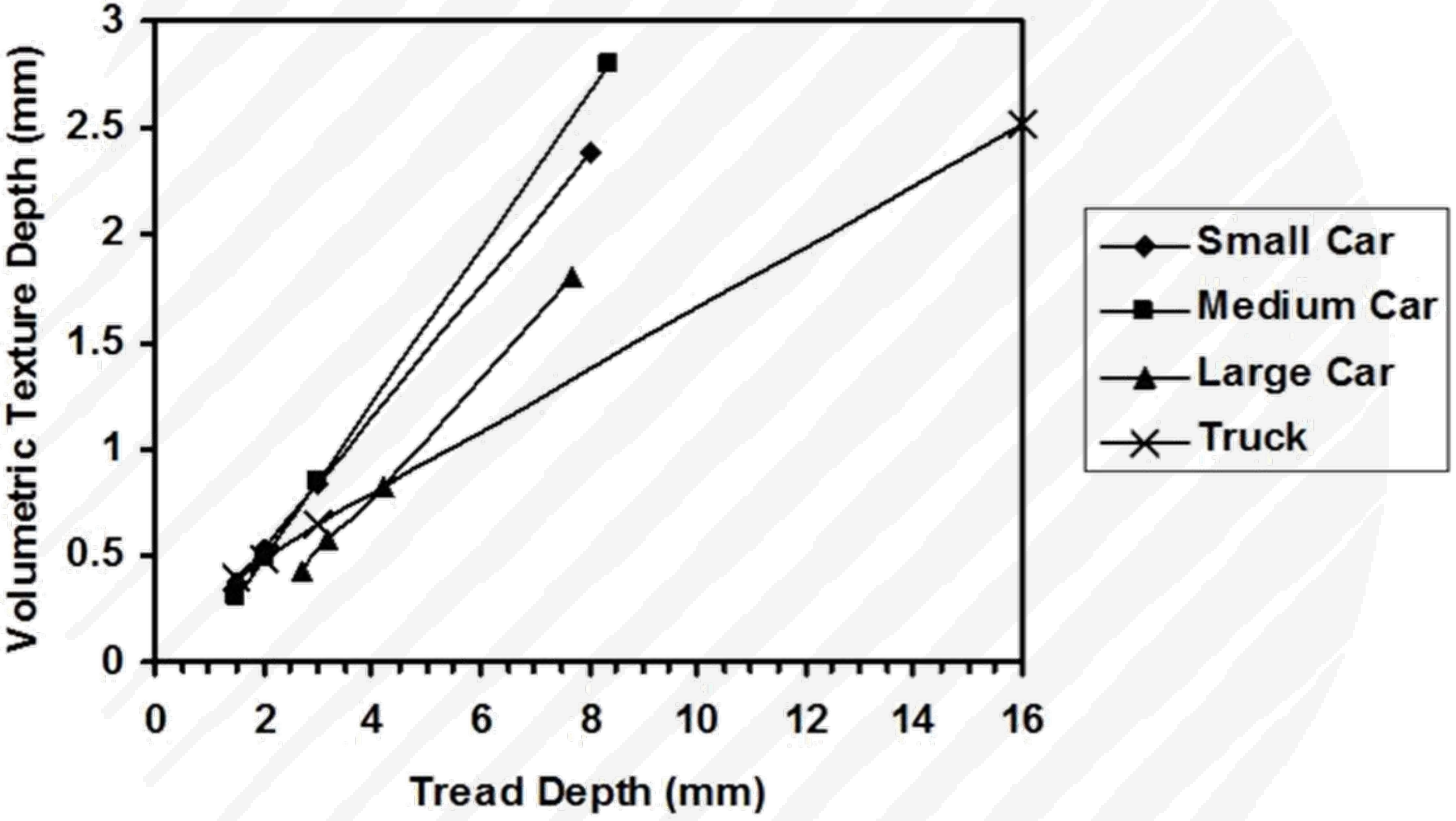
F_{60} = IFI harmonized wet coefficient of friction for 60 km/h slip speed

S_p = IFI speed number (km/h)

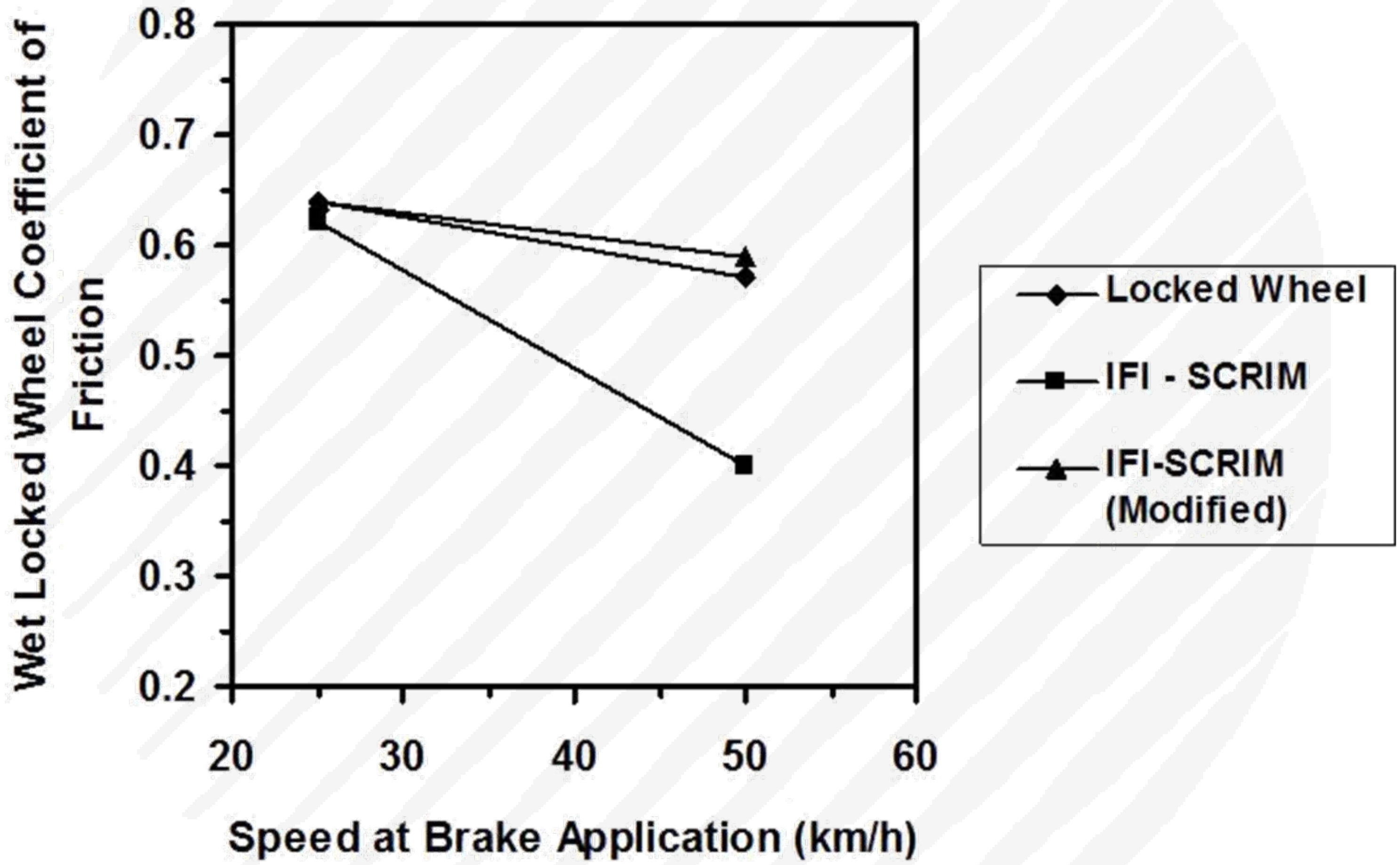
S = slip speed (km/h)

V_B = vehicle speed when locked-wheel braking is initiated

Tread Depth versus Texture Depth



Predicted versus Observed Speed Sensitivities



OPUS Central Laboratories

TNZ Christchurch Trials

Test Section	Texture Measurements		Skid Resistance Measurements			IFI Based Calculations	
	SLP (MPD, mm)	Sand Circle (MTD, mm)	SCRIM (SFC)	British Pendulum (BPN)	Wet, 50km/h Locked Wheel Braking (Vericom)	µ50	F50
G3 EB	1.19	1.19	0.47	63.2	0.60	0.54	0.46
AC 16	0.42	0.54	0.60	65	0.68	0.67	0.48
AC 16 G	1.34	1.13	0.68	85.4	0.71	0.77	0.66
G6 EB	1.41	1.44	0.71	77	0.71	0.80	0.70
G3 EB	1.91	1.65	0.52	63.2	0.60	0.60	0.54

Source: Austroads Technical Report AP-T72/06

Design Values of Friction

Austroads sealed road values for stopping sight distance:

Design Speed (km/h)	Coefficient of Longitudinal Deceleration
50	0.52
60	0.48
70	0.45
80	0.43
90	0.41
100	0.39
110	0.37
120	0.35
130	0.32

Speed Change	Percentage Drop in Coefficient of Longitudinal Deceleration
50km/h – 130 km/h	36.5%
70 km/h – 130 km/h	26.7%
50 km/h – 70 km/h	13.5%

Suggested Minimum Value

SCRIM Coefficient = 0.46

or

British Pendulum Number = 48

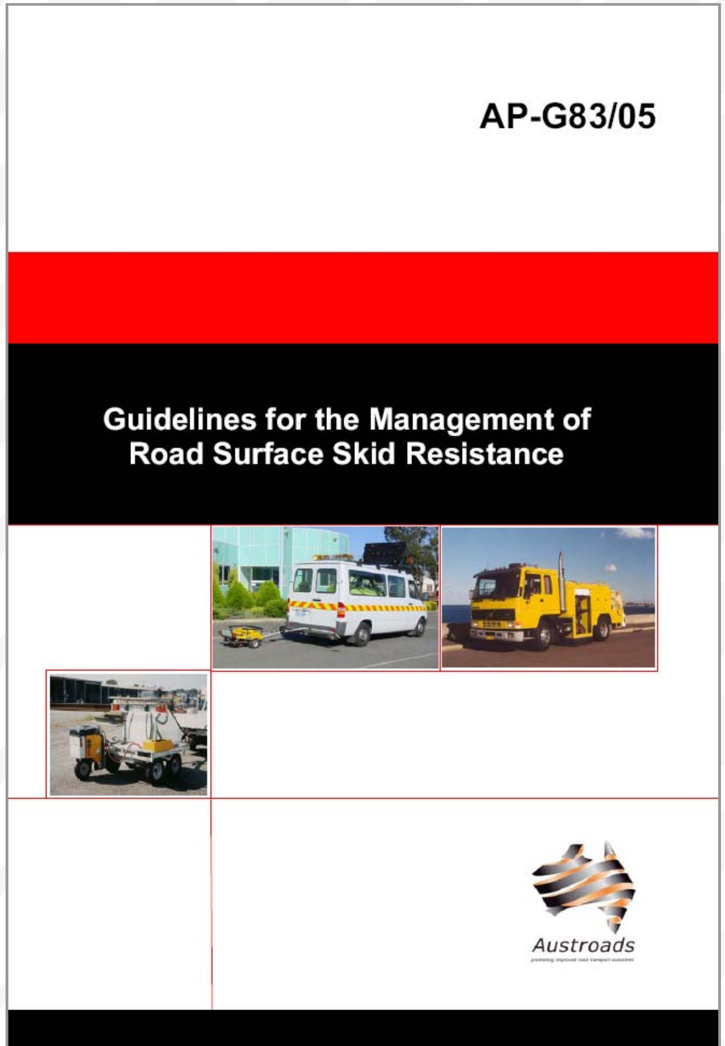
and

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.

Austroads Publication AP-G83/05

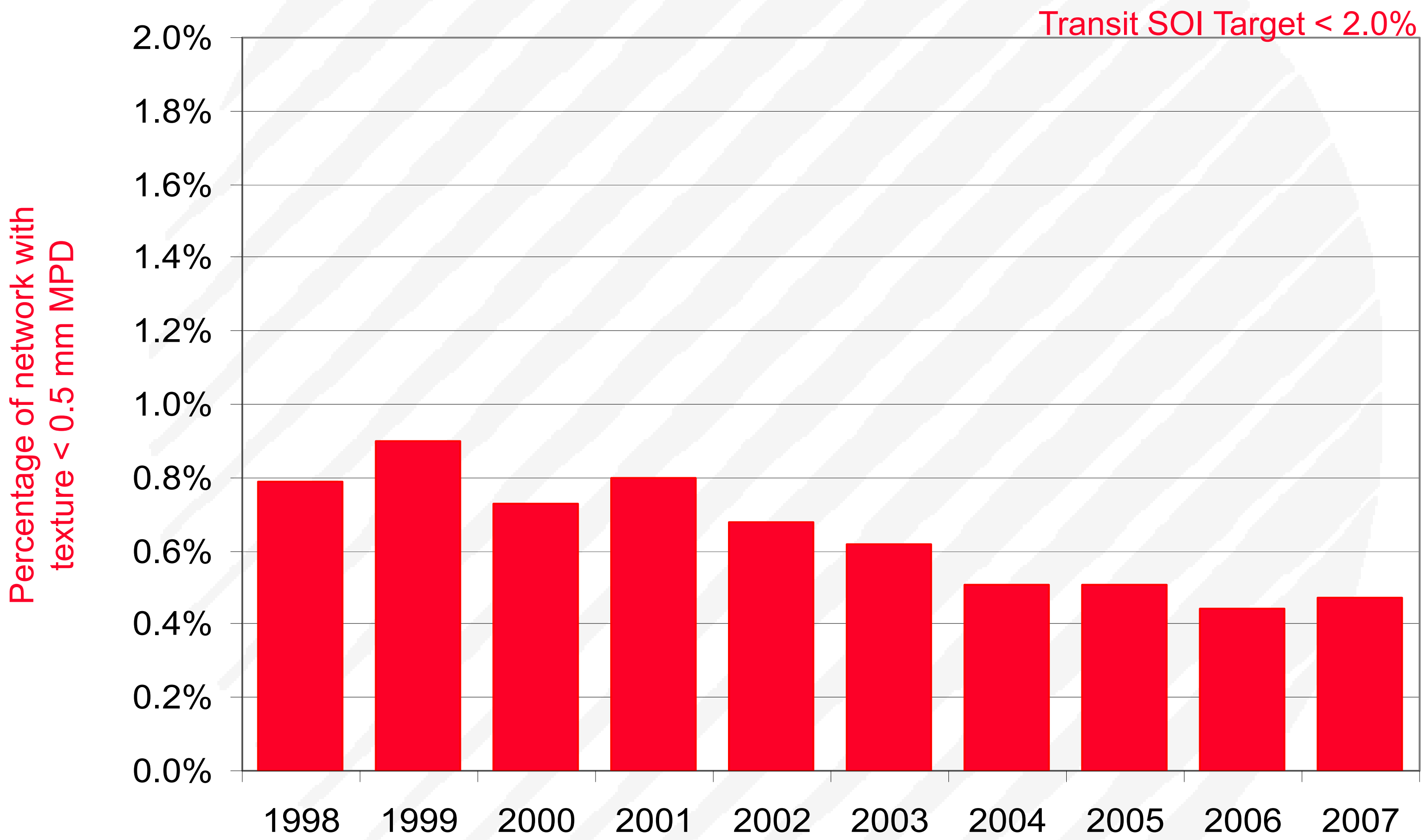


Examples of Successes

- 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.

Network Texture

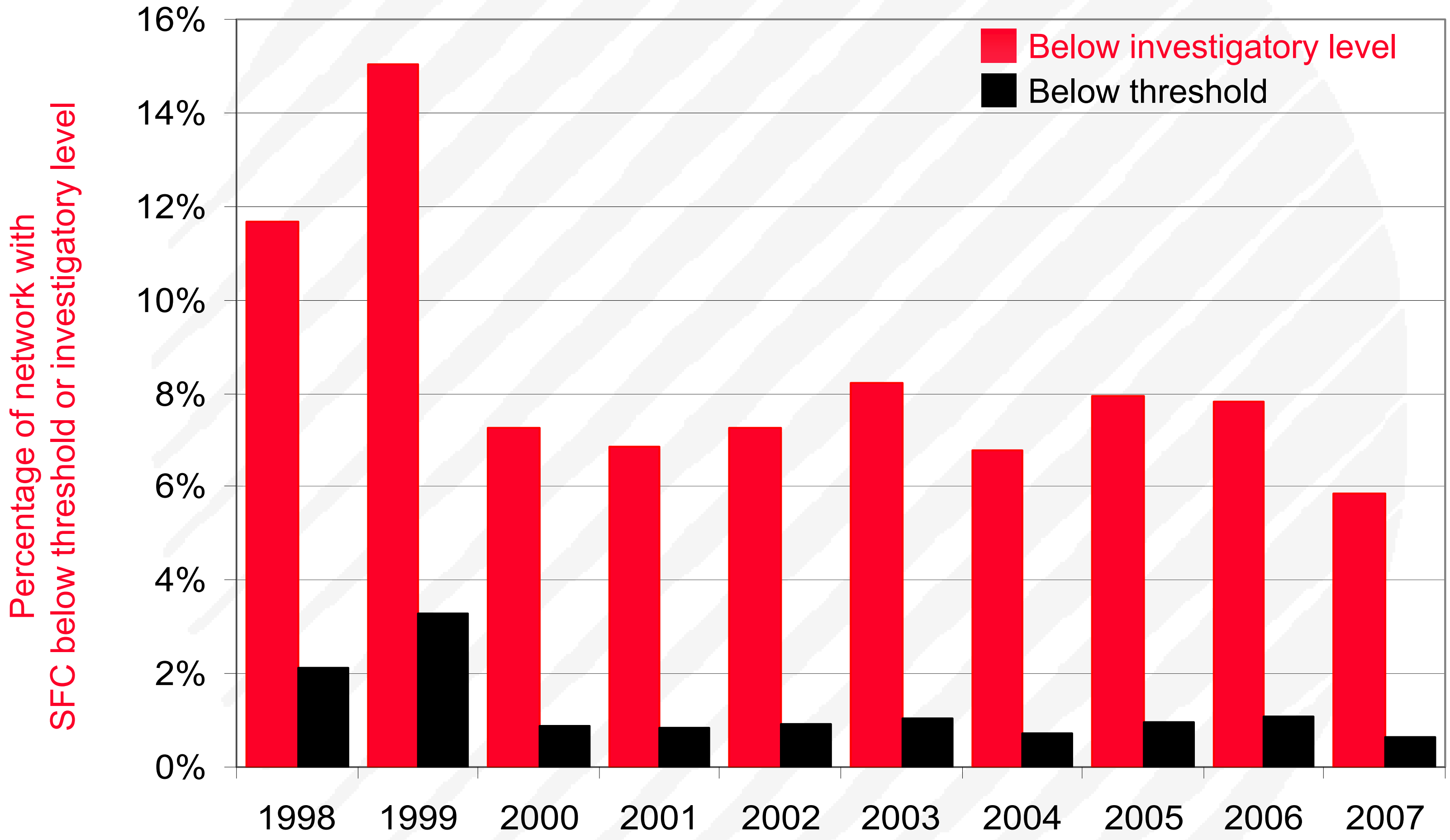
Rural all surfaces; Urban only chip seal surfaces



Source: 2007 TNZ State Highway Pavement Condition Report

OPUS Central Laboratories

Network Skid Resistance



Source: 2007 TNZ State Highway Pavement Condition Report

OPUS Central Laboratories

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.

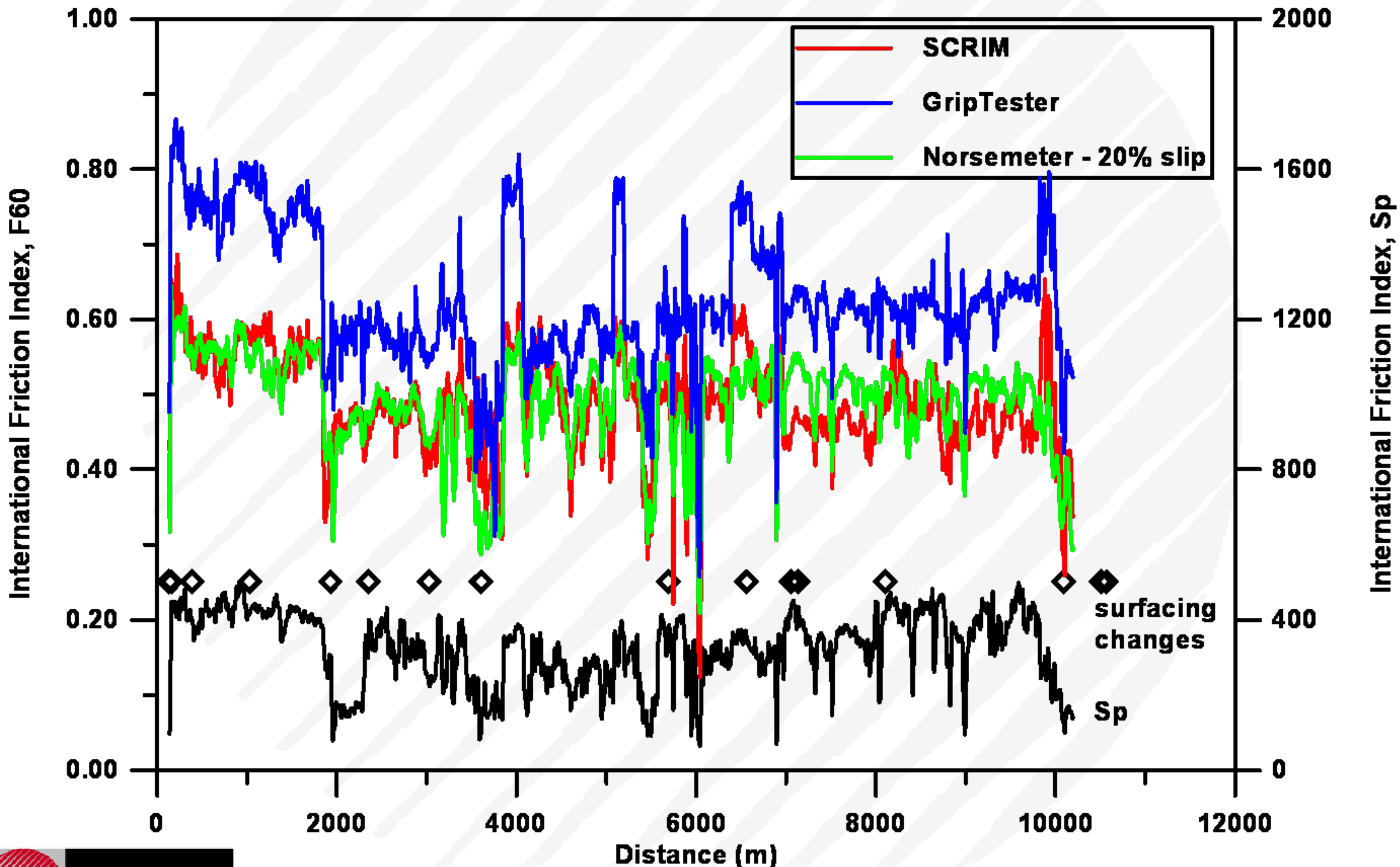
Crash Reduction

- 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

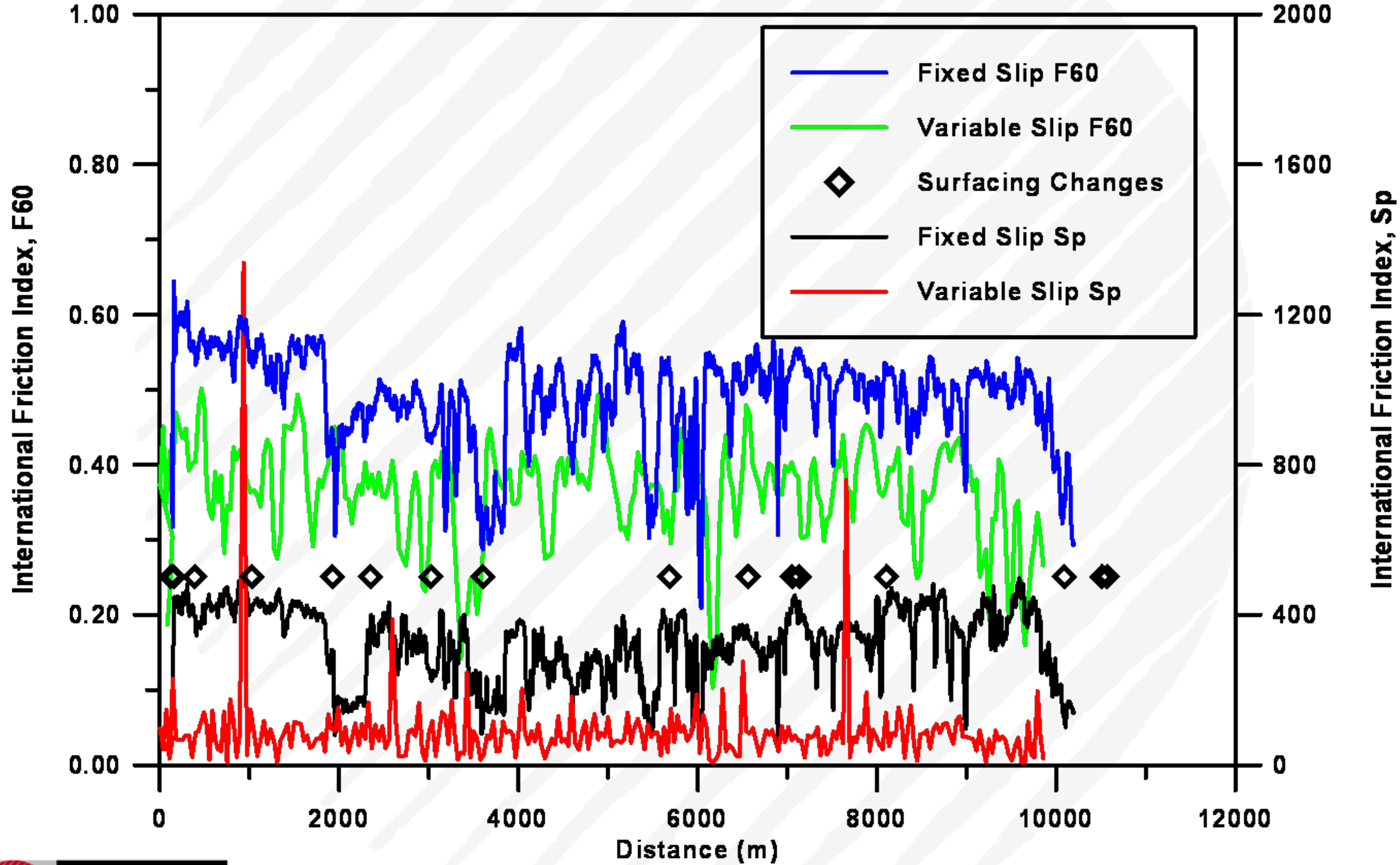
- Closer collaboration between Transit and NZ Police.
- Level of awareness and practitioners' understanding raised.
- Safer driving environment for users of the State Highway network.
- Significant decrease in wet-road loss of control crashes despite increased exposure.
- Improved measurement systems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

International Friction Index



OPUS Central Laboratories

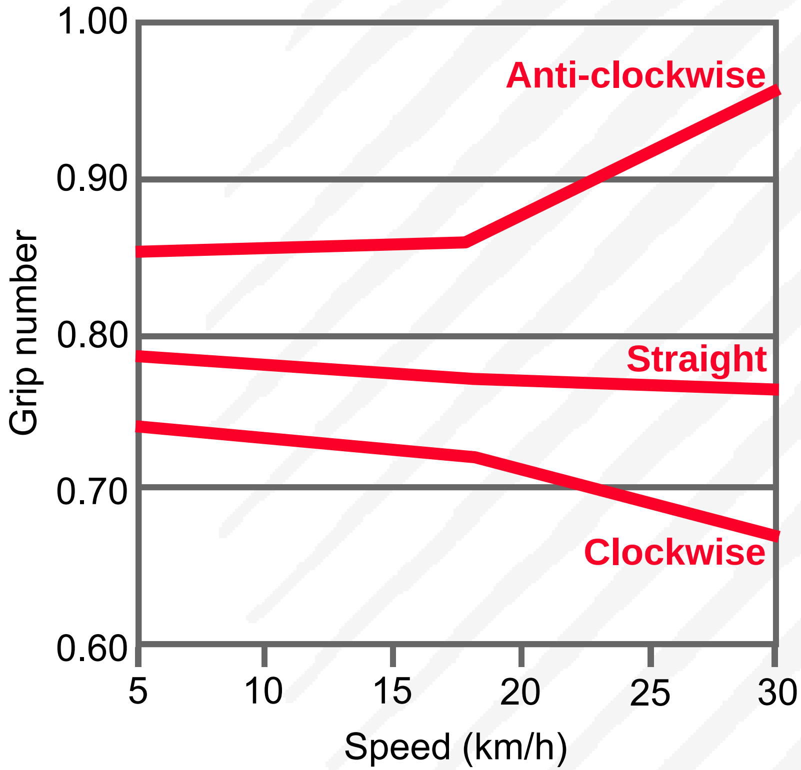
Variable Slip Derived IFI



OPUS Central Laboratories

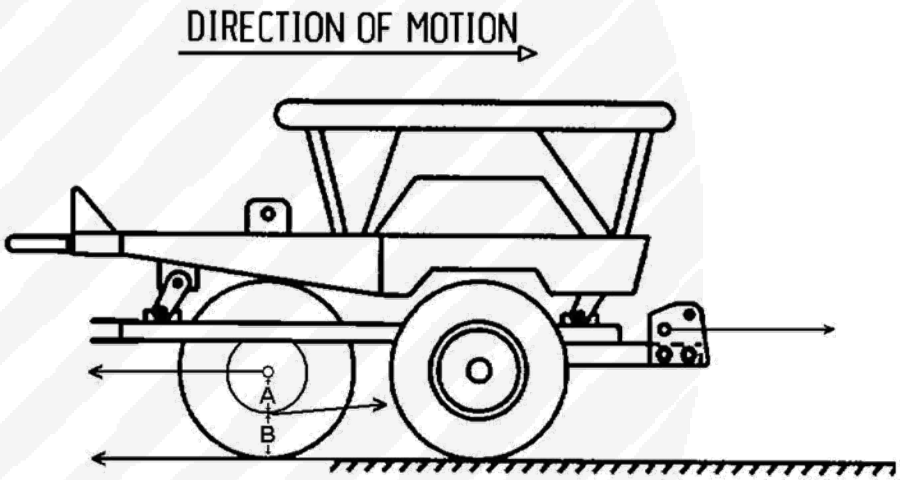
C-type Grip Tester

Cornering



Wear of measuring tyre

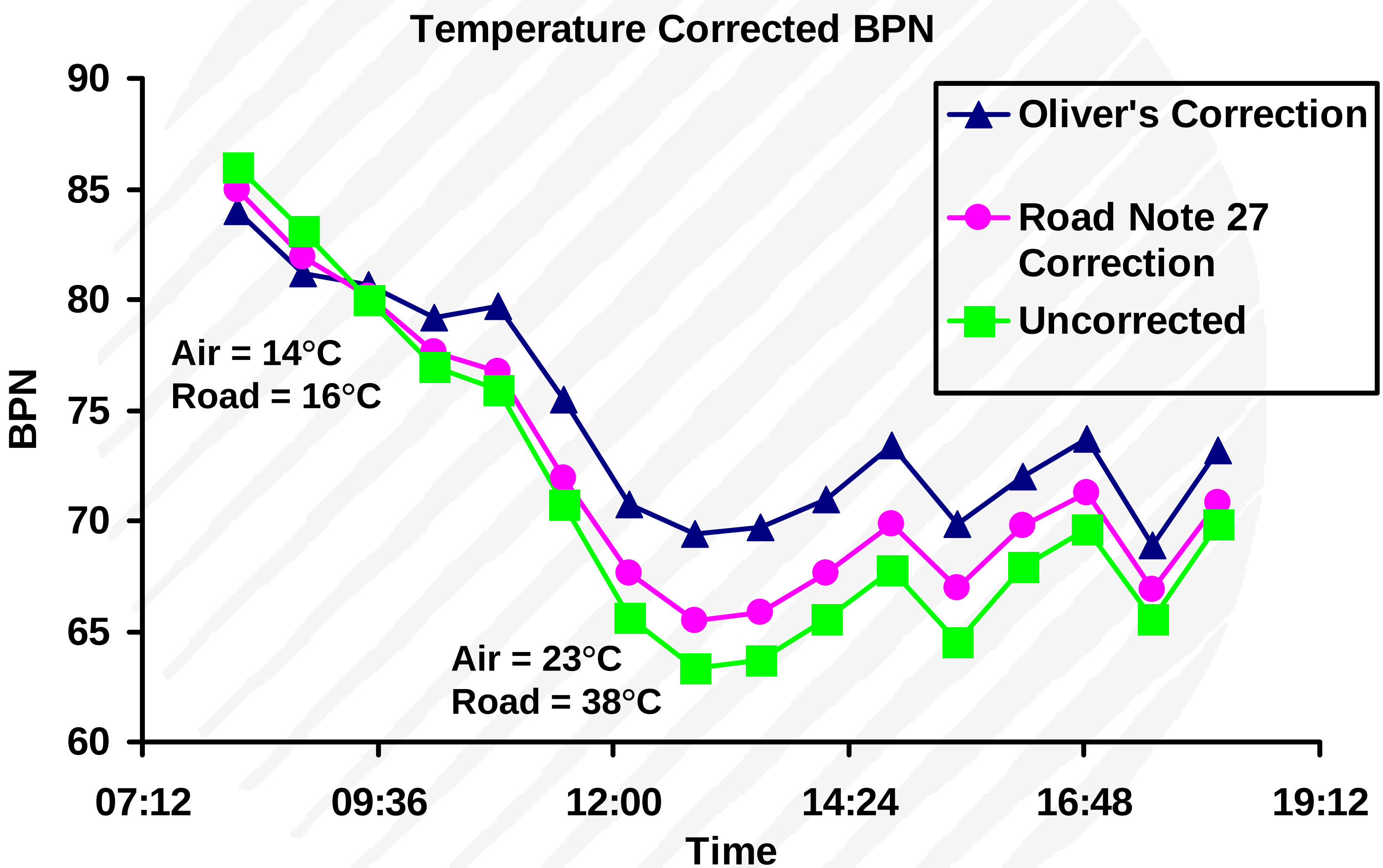
(0.06GN variation)



A = 65 mm (fixed)

125.15 mm ≤ B ≤ 130 mm
(varies according to tyre wear)

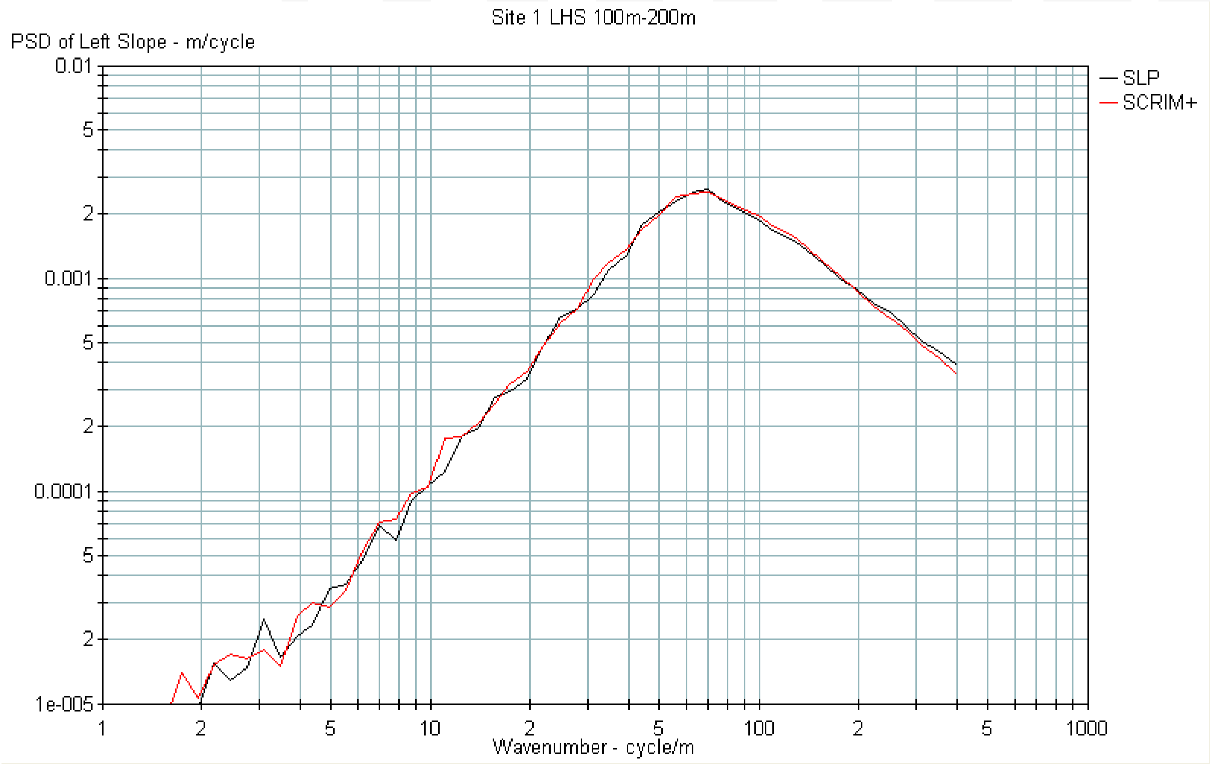
Temperature Corrected BPN Variation



OPUS Central Laboratories

Spectra Based Validation

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



OPUS Central Laboratories

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!

Model Form

$$\text{Expected crash rate } (10^8 \text{ vkt}) = a.e^L$$

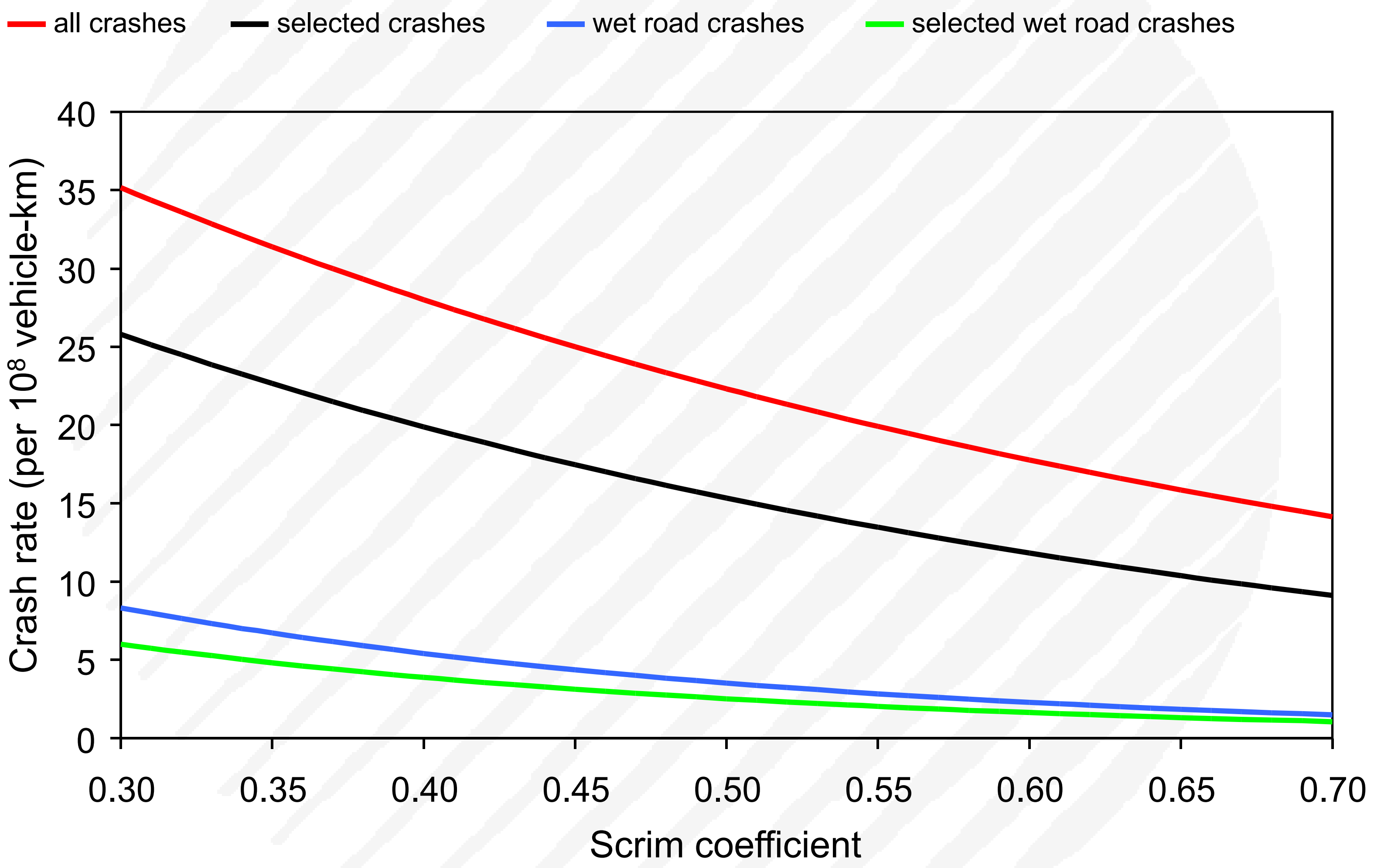
Where:

- a = $10^{10}/365$
- L = 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)
  - $\log_{10}$(horizontal curvature)
  - $\log_{10}$(ADT)
  - absolute gradient
  - $\log_{10}$(IRI)

EBOP SMS

Source of Crash Numbers	Annual Average Mid Block Crashes			
	SH2 RS 194/0-10km		SH30 RS232/0-11km	
	All Injury	Wet Injury	All Injury	Wet Injury
CL Model	2.35	0.39	1.94	0.35
CAS (2001-2005)	3	0	1.8	0.2

Crash Rate versus SCRIM Coefficient

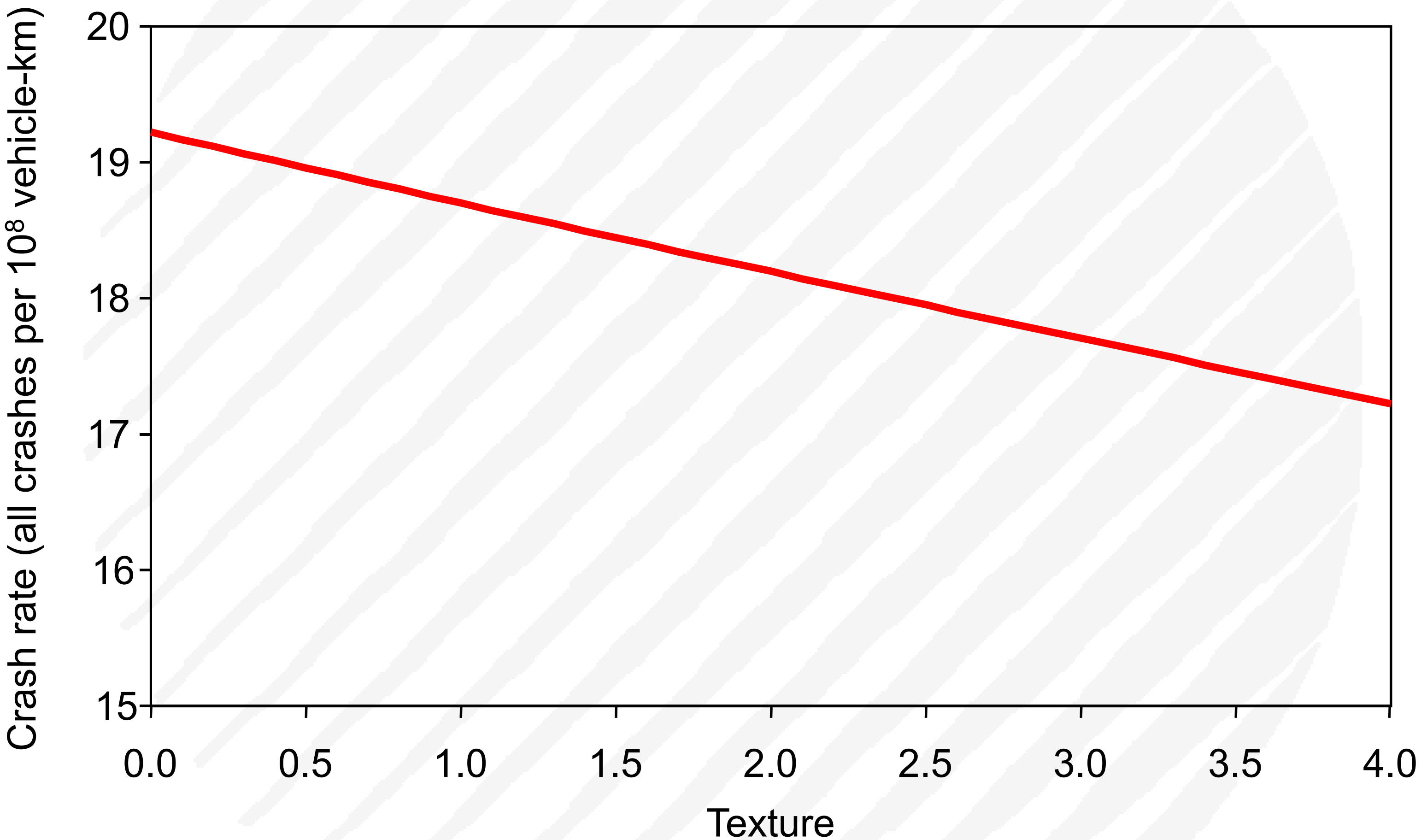


OPUS Central Laboratories

Effect of Skid Resistance:
Reduction in Crashes per 10^8 v-km

Change in SCRIM SFC	All Crashes		Wet Road Crashes	
	%	Actual	%	Actual
0.35 to 0.45	20%	6.4	35%	2.3
0.55 to 0.65	20%	4.1	35%	1.0

Crash Rate versus Texture



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.

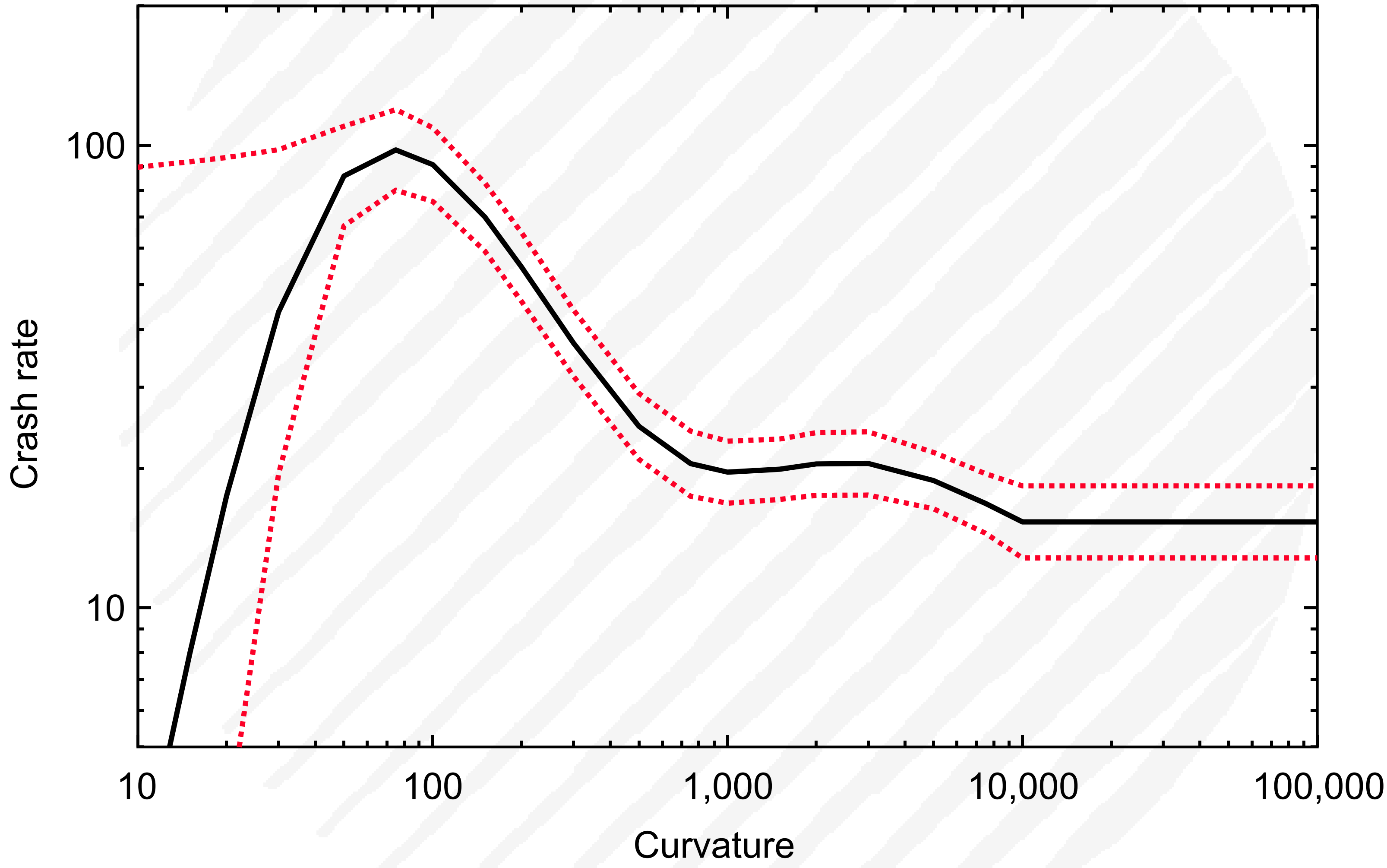
Main Lessons Learnt

- 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



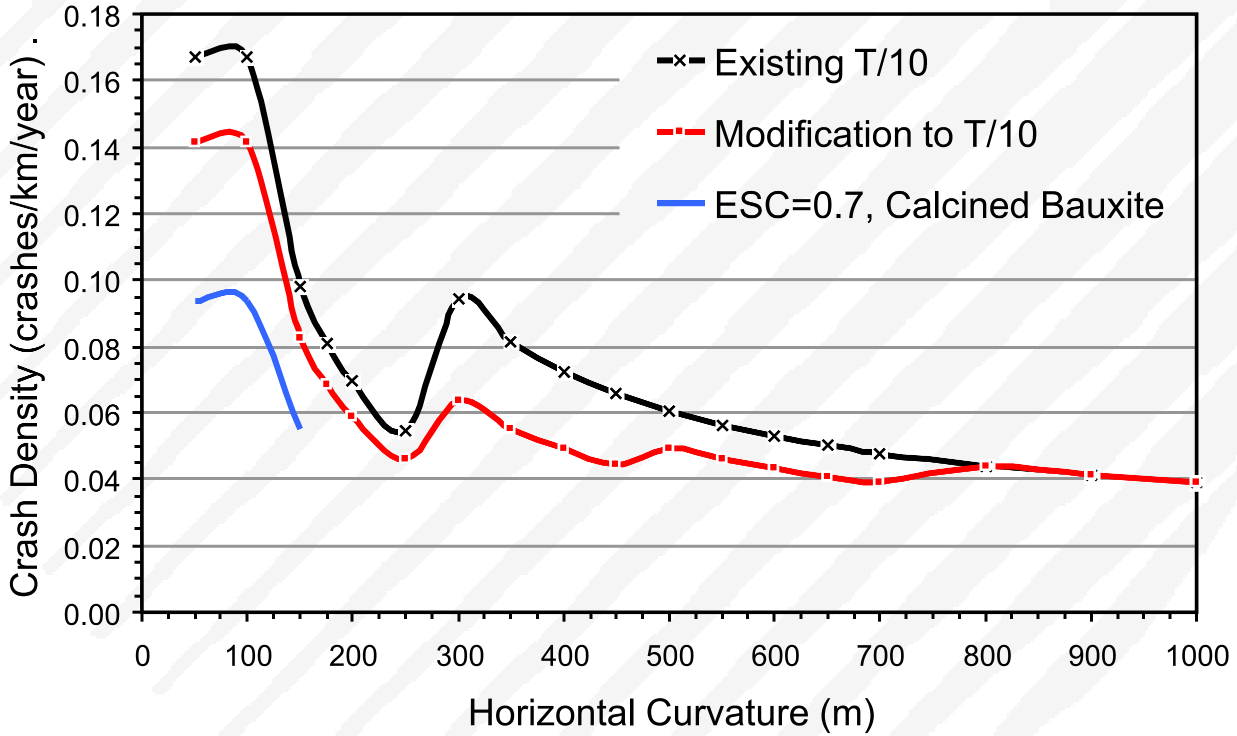
OPUS Central Laboratories

Two Candidate Approaches

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

Possible Revision to T/10

Curve Radius (m)	SCRIM SFC	
	Existing T/10	Modified
≤ 250	0.5	0.55
251 - 450	0.4	0.5
451 - 700	0.4	0.45



OPUS Central Laboratories

Risk Ranking of Curves

• High	approach speed exceeds curve speed by ≥ 15 km/h
• Low	approach speed exceeds curve speed by < 5 km/h
• Medium	all remaining curves
• High (+DG)	downhill gradient ≥ 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 Injury Crashes: 1007 (1997-2006)
- Total No of Curves: 400
- High risk curves = 3.6 crashes/curve
- Medium and low risk curves = 2.2 crashes/curve

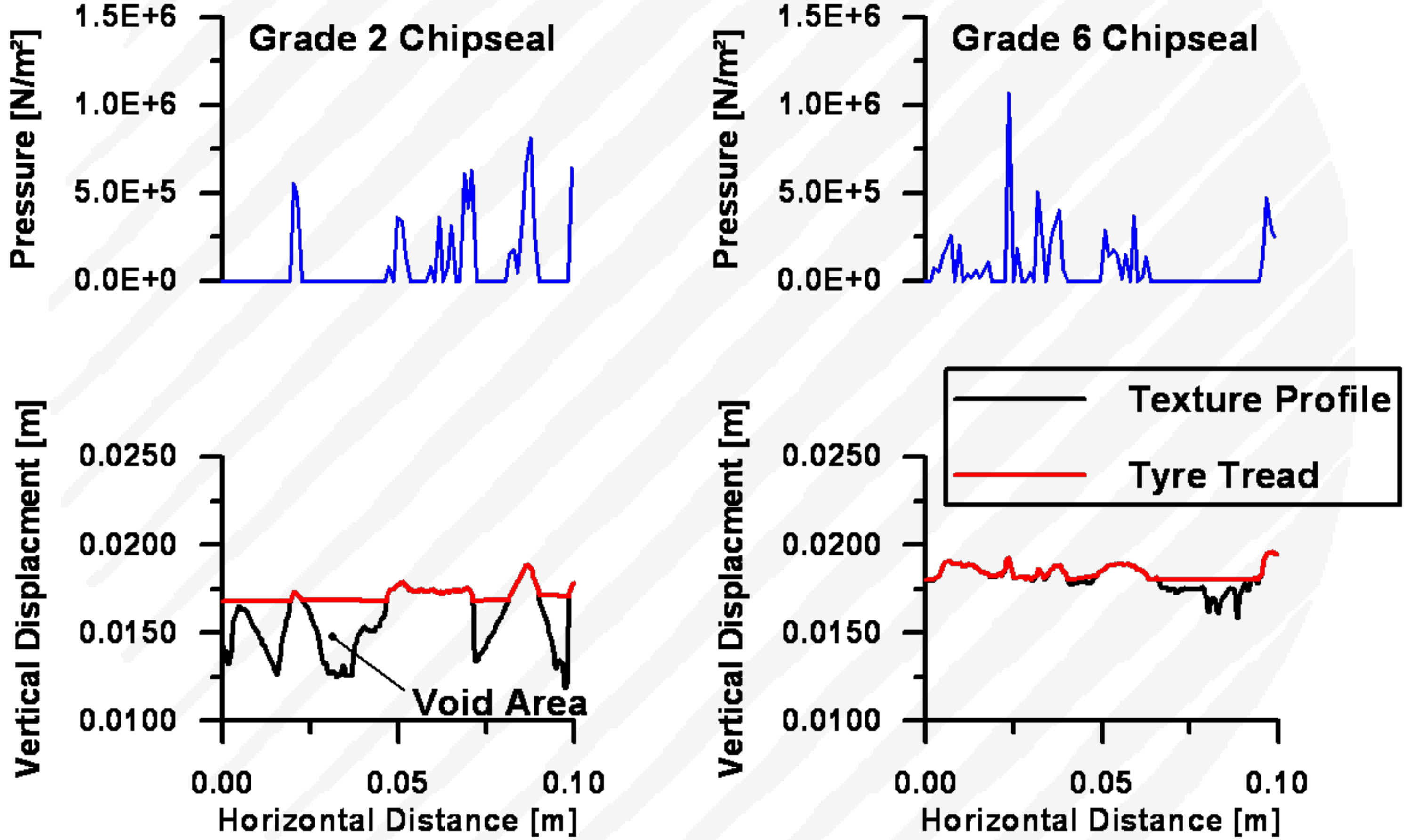
BPT Measurements on Selected Curves

Corner	Turning	Radius (m)	BPN Wheelpath Ratio (Outside / Inside)	BPN Ratio (Longitudinal / Radial)
2	Left turn	210	1.05	1.04
4	Left turn	80	1.02	1.10
5	Left turn	40	1.09	1.05
8	Right turn	170	1.03	1.08
6	Right turn	120	1.06	1.04
3	Right turn	40	1.04	1.15
Average all corners:			1.05	1.07

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



OPUS Central Laboratories

Perceptions of the Next Decade

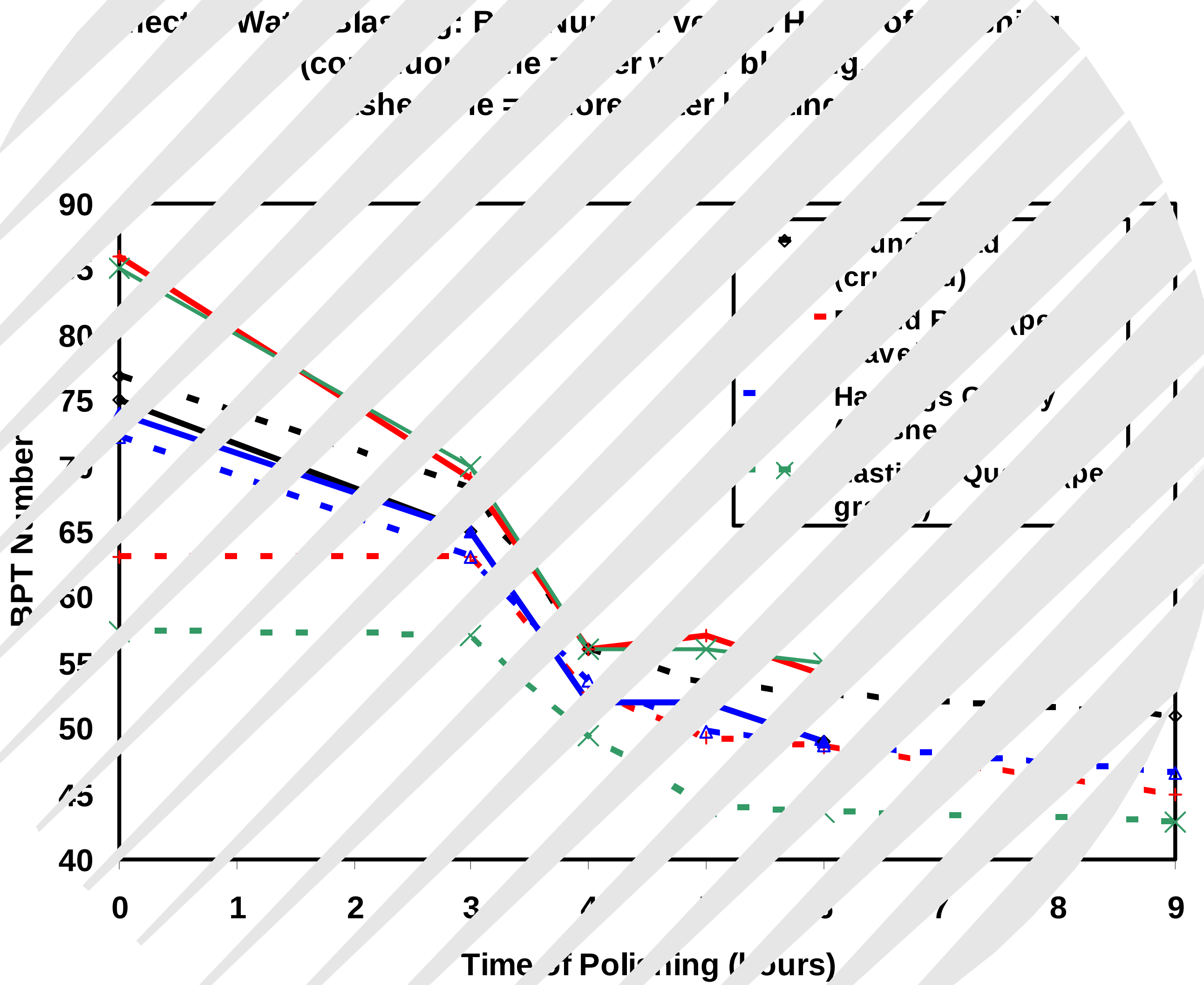
- Increasing role of road surface texture.
- Recycling or rejuvenation of existing road surfaces.
- Systems approach to road safety management.
- Need for adaptive policies to deal with climate change.

High Pressure Water Blasting

Before Treatment

After Treatment

Hig … ting

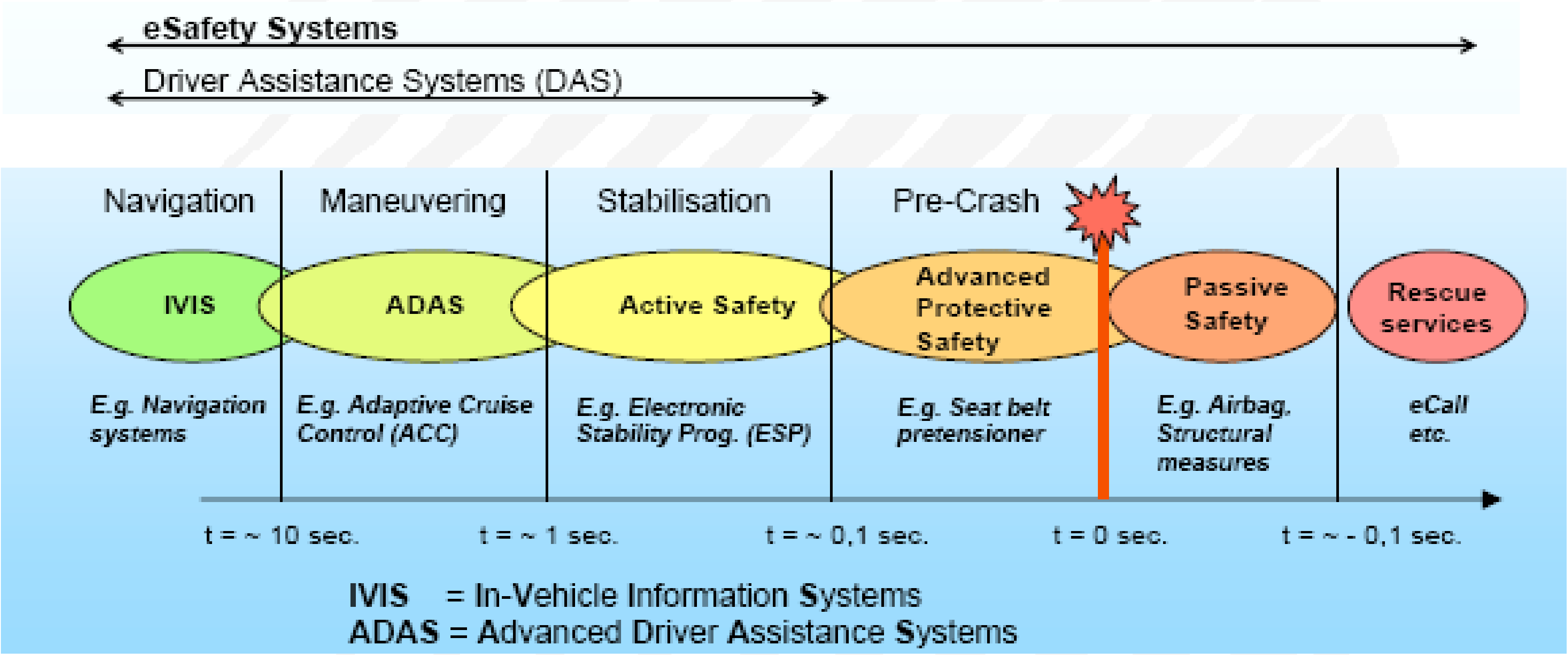


OPUS Central Laborat… ies

Perceptions of the Next Decade

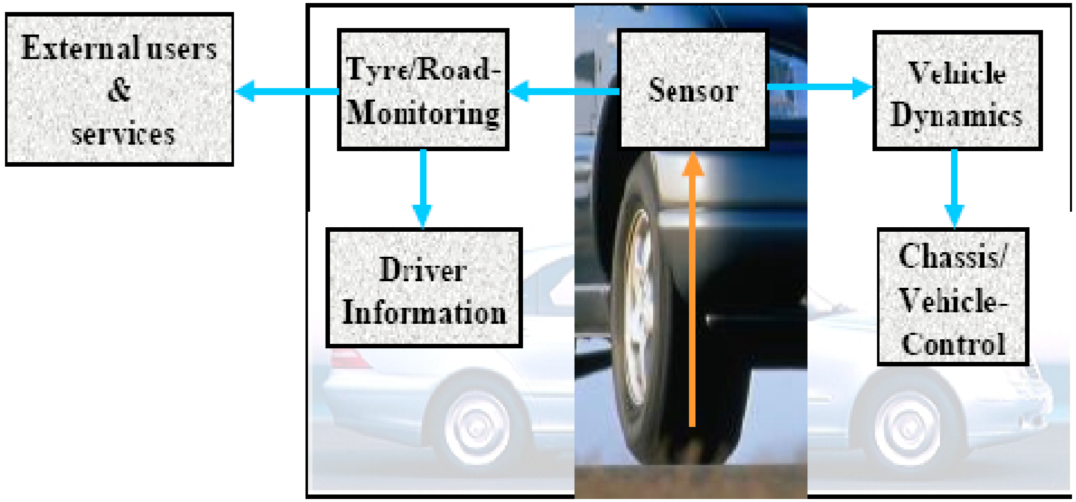
- Increasing role of road surface texture.
- Recycling or rejuvenation of existing road surfaces.
- Systems approach to road safety management.
- Need for adaptive policies to deal with climate change.

Electronic Safety Systems



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

Intelligent Tyre – APOLLO Project



Vehicle dynamics	Tyre	Road
- Forces/torques - Friction parameter - Speed, slip - Maximum contact force - Detecting aquaplaning	- Pressure - Temperature - Tread water - Damage, stress - Tyre type - Age - Logistic parameters	- Texture of road surface - Type of road: concrete, asphalt - Road condition: dry, wet, icy, snowy

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

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