Traffic Speed Deflection Data Applied To Network Asset Management – An Informative Reality Check

TSD Coverage (Uncalibrated) - Direct application N/A.

TSD Evaluation

Application elsewhere: 2017 Europe, SA, UK US

Empirical approach (SCI, Structural Number –SNC/SNP) for remaining life

US: AASHTO 93. “Nothing could be more nebulous” US NCHRP 2004 http://onlinepubs.trb.org/onlinepubs/archive/mepdg/Part1_Chapter1_Introduction.pdf

Mechanistic approach (stresses, strains and moduli)

Hit rate documentation for each? 80/20 The Data Deluge <- SN -E M-E ->

Aspects of structural evaluation (FWD and/or TSD) that are, or would be, desirable for more efficient network asset management:

1. Sub-sectioning: Determining extents for each structurally homogeneous sub-section
2. Potential for improvements from subsurface drainage, and effects on FWP
3. Remaining Service Life RSL. (Terminal using NPV) &
4. Terminal Distress Mode

Aspects of FWD/TSD Evaluation

1. Determining extents for each structurally homogeneous sub-section (STL)
2. Potential for improvement from subsurface drainage, and effects on FWP
3. Remaining Service Life (from NPV) &
4. Terminal Distress Mode ->
5. Most appropriate form of rehabilitation ->
6. Budget $ per treatment length (NPV) or $/ESA/lane km
7. Priorities and Optimised Forward Work Programme (integrating the effects of subsurface drainage, structural maintenance and eventual rehabilitation) ->
8. Total budget for FWP - Cumulative (25 year) Annual Expenditure

Potential: (TSD specific)

Economics for ongoing heavy (structural) maintenance vs wider rehabilitation ($)

1-2%/year 0.5-1%/year

Mechanistic Methodology: Multiple Distress Criteria

Framework proposed originally by Andrew Dawson (Nottingham):

International workshop for the development of Mechanistic Design Methods for Unbound Pavements

23 distress modes for RSL

1or 2 for unbound design

Design vs RSL …. x 10

Thick Structural AC – Ullidtz model (3 distress modes)

Rutting →
Roughness →
Degradation →
Flexure →
Shear →

1	Excess resilience of pavement (see also Mechanisms 6 and 7)
2	Excess rutting from within granular layer due to granular material shear displacement
3	Excess rutting from within granular layer due to compaction by traffic loading
4	Excess rutting from within subgrade layer due to subgrade shear displacement
5	Excess rutting from within subgrade layer due to combined action of subgrade and granular layer(s)- due to complex stress interaction effects
6	Excess rutting from within subgrade layer due to combined action of subgrade and granular layer(s) when subgrade is too resilient
7	Pumping of subgrade into base course
8	Excess longitudinal roughness - uneven-ness
9	Excess longitudinal roughness - potholing
10	Excess longitudinal roughness - corrugations
11	Frost action on susceptible subgrades or granular materials
24	Breakdown of pavement aggregate due to repeated freeze-thaw cycling
25	Softening of the pavement at the time of Spring-thaw
12	Soil heave / shrinkage
13	Wear due to dust loss
14	Wear due to stone displacement by tyre ('gravel loss')
26	Wear due to stone 'loss' into soft subgrade ('gravel loss')
27	Wear due to erosion of surface metalling by water ('gravel loss')
15	Wear due to stone abrasion / attrition
16	Wear due to studded tyre action
17	Seal breakage due to traffic-induced flexure
18	Seal breakage due to environmentally-induced shrinkage (thermal cracking)
19	Seal breakage due to shoving / tearing / shearing
20	Inadequate surface condition- sealed surface too smooth due to aggregate texture loss
21	Inadequate surface condition- sealed surface too smooth due to excess bitumen rising to surface
22	Inadequate surface condition- unsealed surface too slippery due to excess fines on surface (wet weather)
23	Inadequate surface condition- unsealed surface too slippery due to loose gravel on surface

NB Shaded mechanisms largely set aside by workshop - see Section 3.1 and following

Andrew Dawson, 2002

Links:

Briefing Paper - Andrew Dawson

Workshop Outcome - Andrew Dawson

Mechanistic Analysis – Distress Modes

Structural distress modes

1 Shallow Shear – Low Strength (shoving)
2 Shallow Shear – Spreading (strong but inadequate support)
3 Shallow Shear – Heave (in loose or low broken faces BC)
4 Shallow Shear – Hybrid (from above)
5 Aggregate Instability (pumping >75%S, potholing, heave)
6 Aggregate Rutting (VSD in base course or subbase)
7* Aggregate Weathering (mineralogical changes in fines)
8 Aggregate Degradation (physical generation of fines)
9 Cracking (conventional, bottom up) of bound layers
10 Flexure (top down cracking) of bound layers
11* Binder Curing/Hardening (aging)
12* Bond loss (cement bound reverting to unbound)
13 Subgrade Rutting (vertical deformation)
14 Subgrade Shear (lateral and vertical deformation)
15 Accumulated Deformation (multiple layers contributing)
16 Slumping/Edge Break (lack of shoulder support)
17 Roughness Progression
18 Shrinkage Cracking (viz FBS with curing/ thermal)

***Typically 12 or more modes* necessary to adequately quantify RSL for any particular form of in-service pavement**

Surfacing distress modes

19 Seal Deformation (more likely as multiple seal layers accumulate)
20 Flexure (top down cracking in seal or thin AC)
21 Reflection Cracking
22* Seal Flushing (binder rise)
23 Scabbing/Raveling

Economic Triggers

24 Excessive Maintenance costs for the surfacing (seal, thin AC)
25 Excessive Maintenance costs for structural layer(s)

Other characteristics or causes that affect timing of triggers include:

26* Loading frequency effects on inter-particle bonds
27* Cement curing
28* Bitumen embrittlement (environmental ageing)
29* Subgrade –subbase intrusion
30* Frost heave
31* Particle breakdown in freeze-thaw cycles
32 Foundation subsidence (vertical depression)
33 Foundation slumping (lateral deformation)

*7, 11, 12, 22 & 26-31 Not explicitly included in current modelling
Vehicle speed and temperature included for individual modes

Regional Precedent Performance (RPP Study)

Inputs:

RAMM Database (LTPP) & Archives

1990-2018 >3M in situ tests analysed FWD & TSD

TSD bowls correlated to equivalent FWD.

Methodology:

- Austroads
- NZ Supplement to Austroads
- NRB Precedent Performance N. Major (1980) The one source of truth
- Feynman Scientific Method Link: Feynman Scientific Method
- Chris Anderson – Big Data: The End of Theory? Link: Big Data: The End of Theory

Regional Precedent Performance (RPP Study)

> 2 decades of mechanistic analyses of FWD & TSD data (>B) -"a unique database" Per Ullidtz

Inputs:
RAMM Database & Archives
1990-2018 >3M in situ tests

Methodology:

- Austroads
- NZ Supplement to Austroads
- NRB Precedent Performance N. Major (1980)
- Feynman Scientific Method
  Link: Feynman Scientific Method
- Chris Anderson – Big Data: The End of Theory?
  Link: Big Data: The End of Theory

The Outcomes / "Fallout"
Before calculating remaining life, calibration for each region is required for:

Austroads Criteria
- 1984 Subgrade strain*
- 1984 Tensile strain
- 1998 Modular ratios*

Load Damage
- 1962> AASHO 4th Power
- 1962> Structural Number (SNP)
- Refer AASHTO 2004 link: http://onlinepubs.trb.org/onlinepubs/archive/mepdg/guide.htm
- 1990's + CAPTIF Mass Limits

Layered Elastic Analysis
- 1990> CIRCLY, Modulus linearity*
- Positive/Negative Non-linearity Stress vs Depth dependence*

Principal Distress Modes
- Pre 1960's 1-2 Rutting – Cracking*
- Basecourse Spec M/4:2006
- RLT

and to:

Forward Work Programme
- B/C (traditional)
- Subsoil Drainage
- Carriageways (vs Lanes)
- Treatment length allocation (dTIMS)
- Surface vs "structural" (dTIMS)

RAMM (conflicts with Austroads)
- Decision on Terminal TL-doc
- Maintenance: LWP vs RWP - doc

Most of the fallout applies to concepts that are decades old and based on limited in situ testing. Reality checks are made quantitatively against the database of over 3 million analyses of in situ testing from *in-service* pavements, the "numbers speak for themselves". Calibrations are essential before remaining life models reflect reality at terminal sites.

Remaining Life Calibration: Using Regional Precedent Performance (Calibration to local terminally distressed sites)

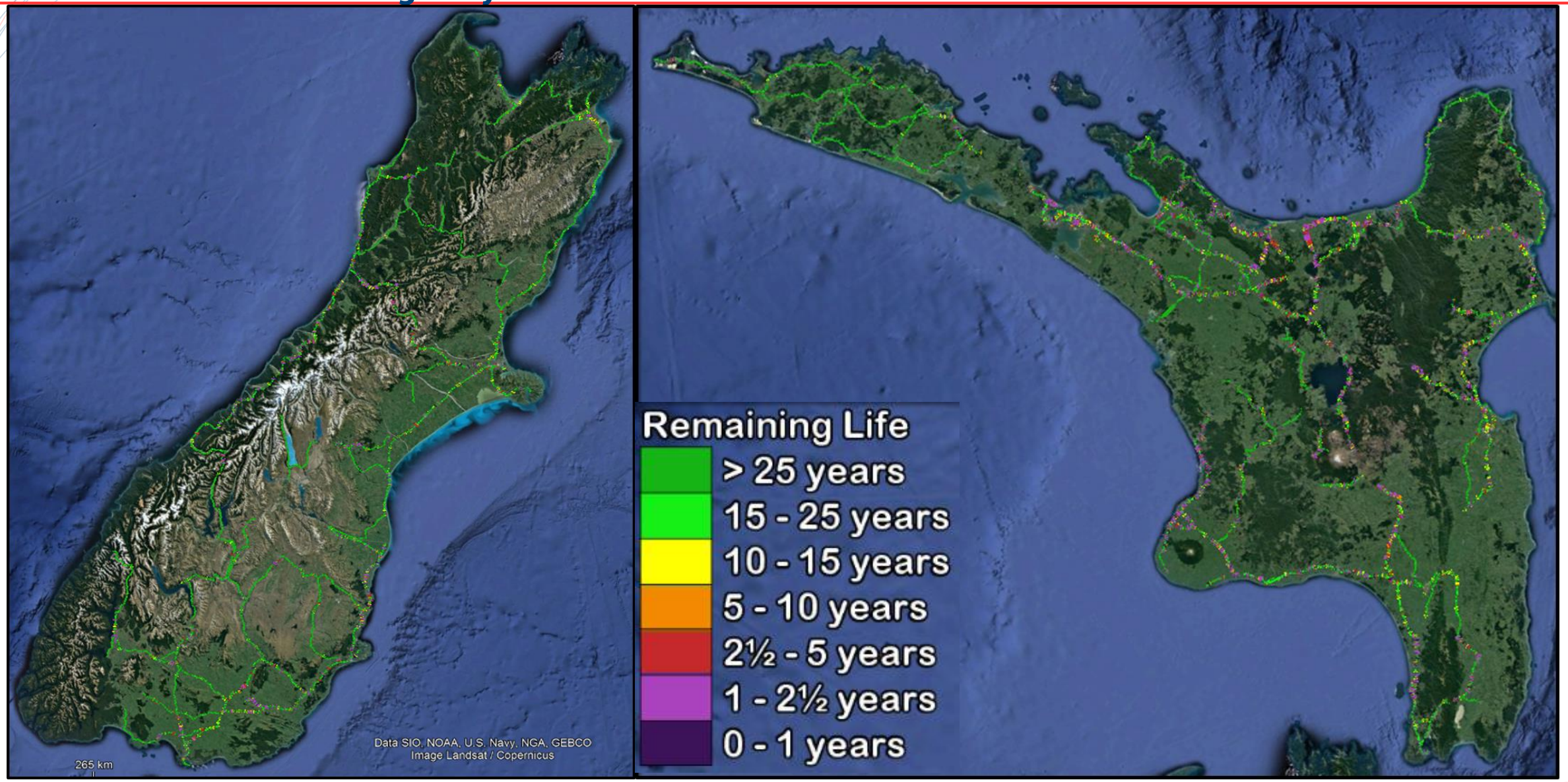
Kaikoura Alternate Route **3-10+ years**
Accelerated Trafficking of In-Service Pavement:
Traffic intensity subject to more than ten-fold increase.

Both FWD and TSD carried out 2015, 2016, 2017 & 2018

Ideal reality check for application, validation and calibration of deflection data for evaluation of remaining life and consequent Forward Work Programme (FWP).

Empirical / Structural Number approach N.A.
Link: Kaikoura ByPass Summary

TSD 2018 Calibration - Goal: Mechanistic analyses and interpretation at 10m intervals for all state highways 80/20

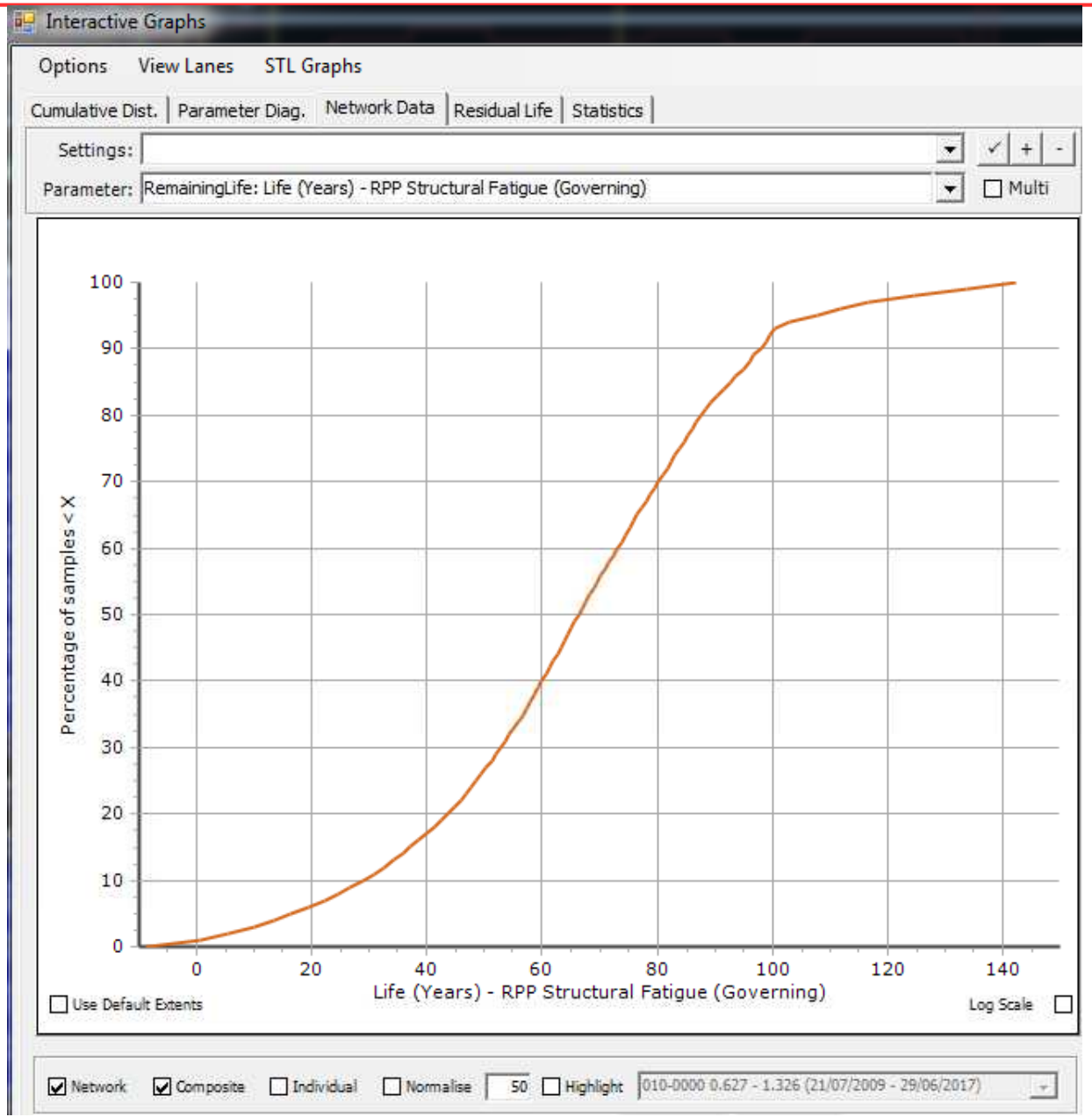


Network Cumulative Distributions

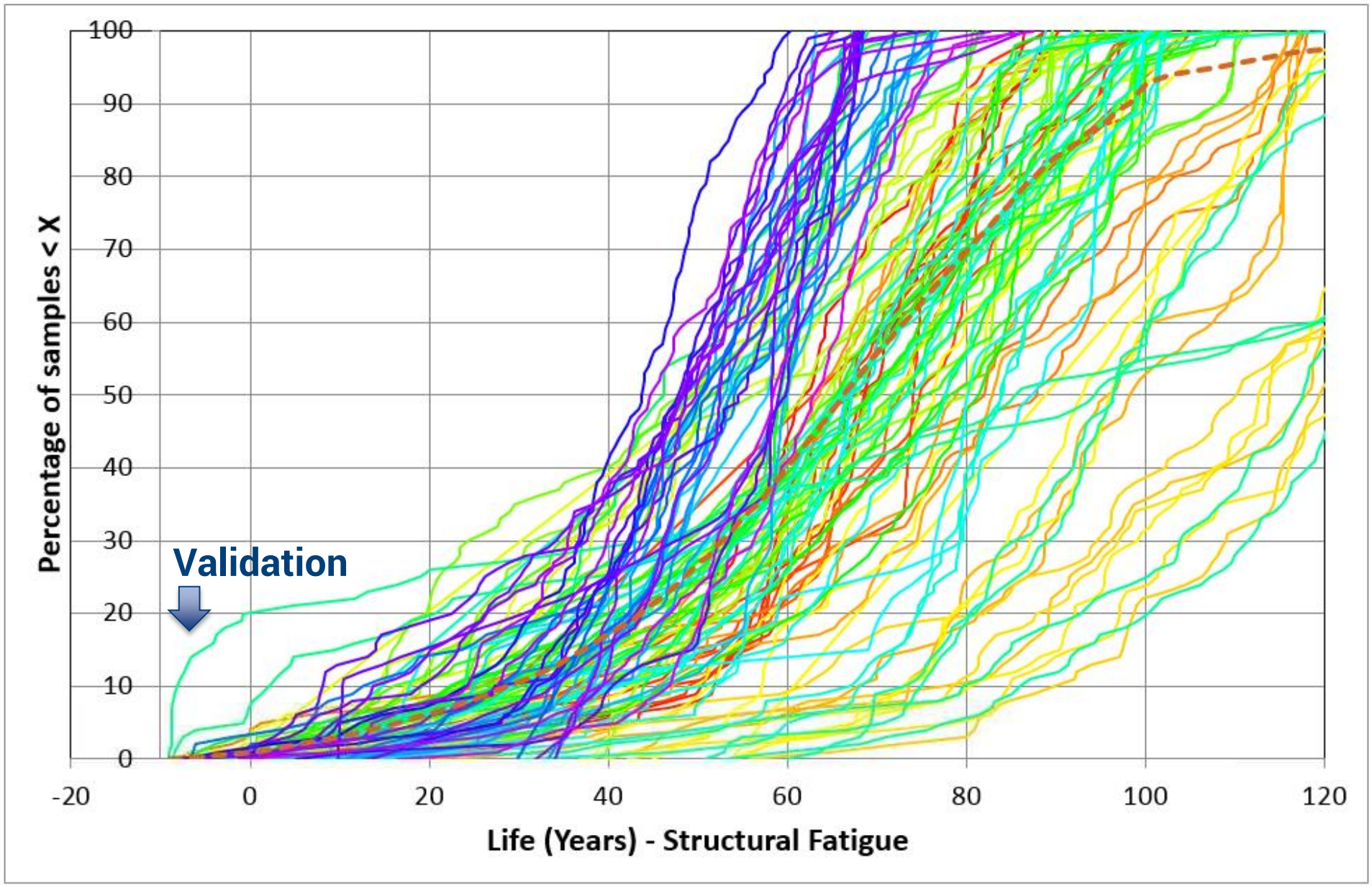
2018 - RPP Remaining Life

All Highways: Region 1

Median Life: 70years



Cumulative Remaining Life RPP (all Route Stations)



Forward Work Programme

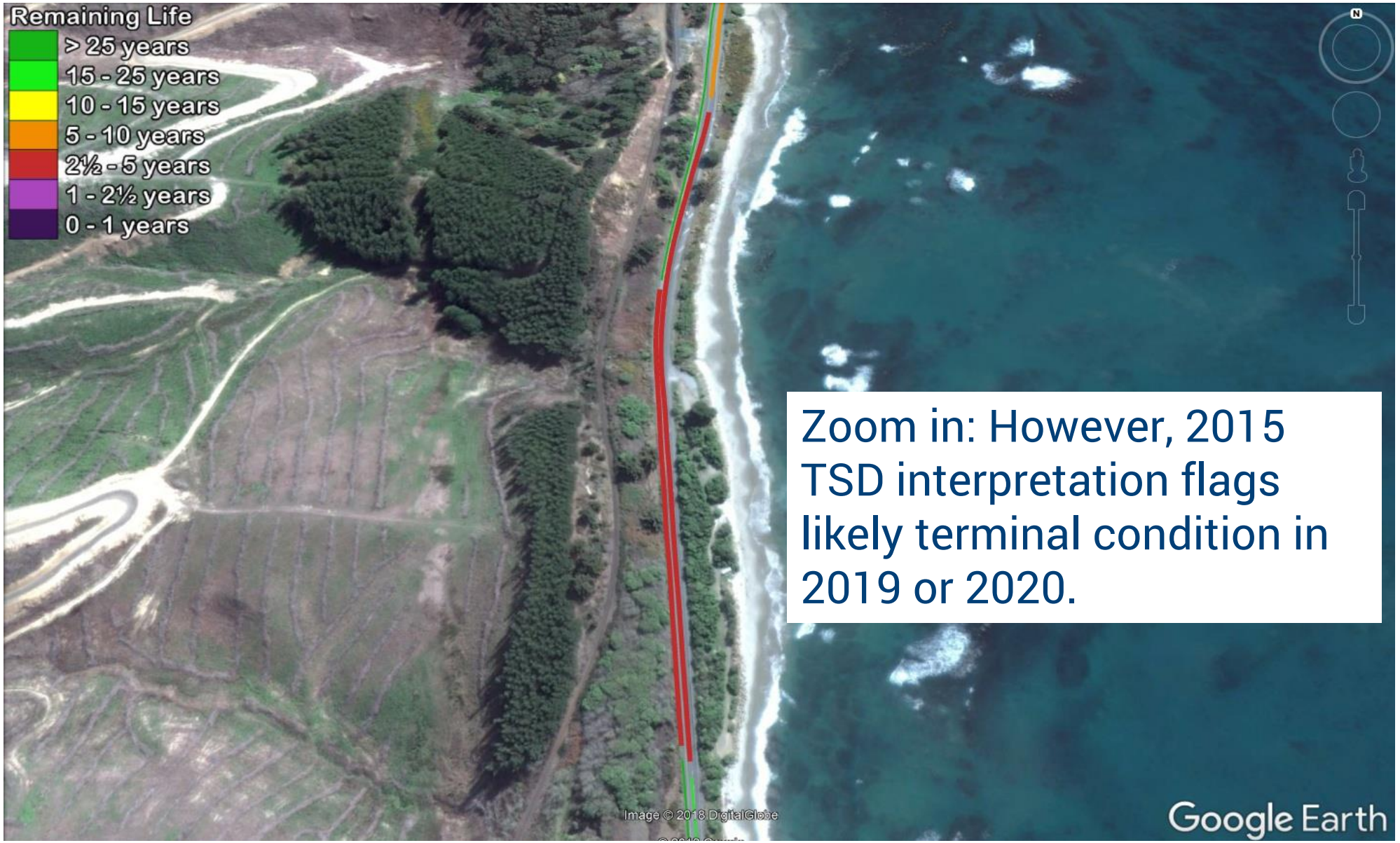
Can TSD provide better advance warning?

3-5 year (and potentially >10 year) prediction

(Case History) State Highway 1: Coastal Otago 3-10 year

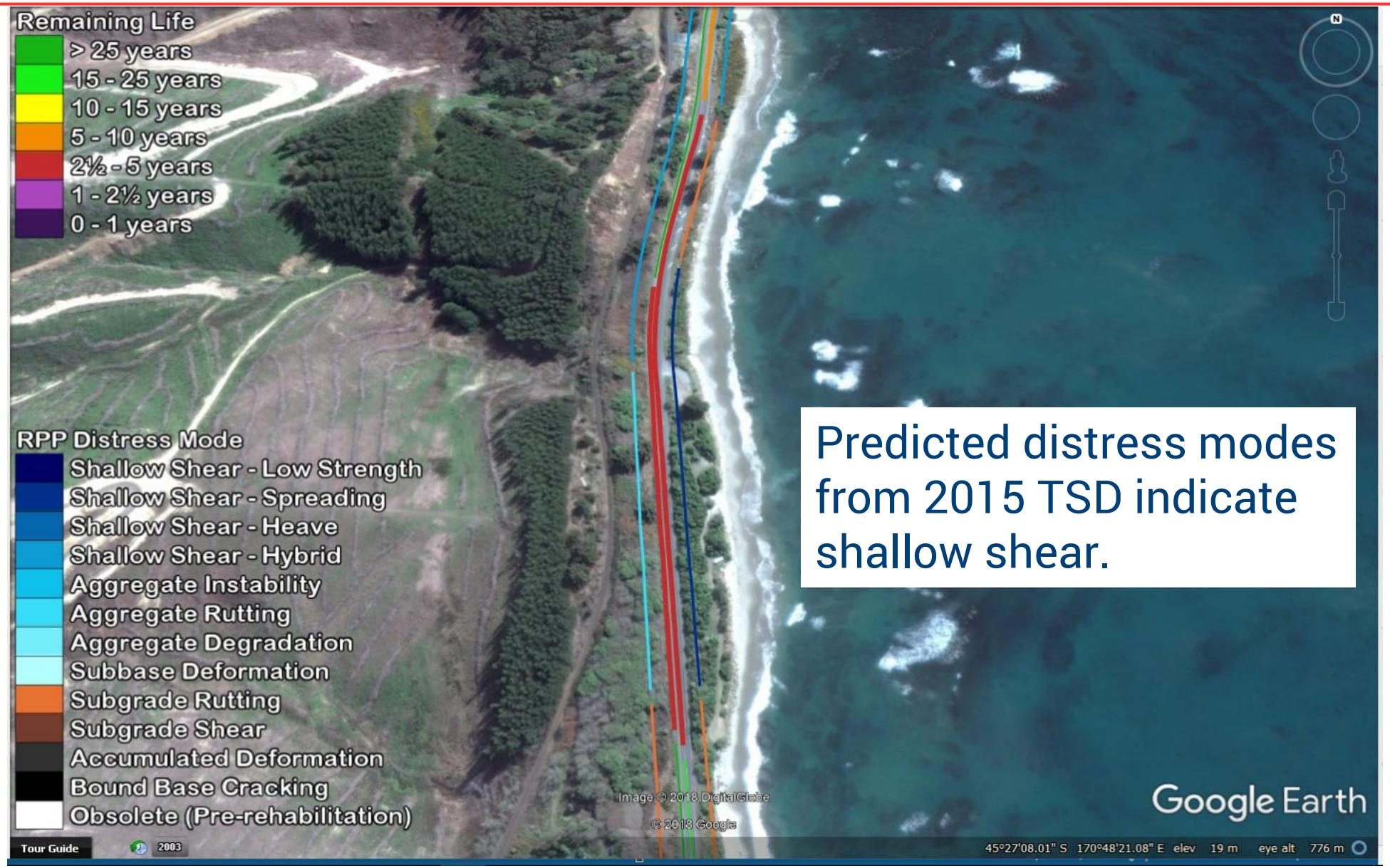
Structural Treatment Lengths
RSL:Target reliability >80%
Tested January 2015. Weakest link on SH 1. In 2017 Agency stated no distress and not on the radar for rehabilitation.

(Case History) State Highway 1: Coastal Otago 3-10 year



Zoom in: However, 2015 TSD interpretation flags likely terminal condition in 2019 or 2020.

(Case History) State Highway 1: Coastal Otago 3-10 year



Predicted distress modes from 2015 TSD indicate shallow shear.

State Highway 1: Coastal Otago 3-10 year

State Highway 1: Coastal Otago 3-10 yr

Same site: if 1-2 years life from now (April 2018) then TSD modelling 2015 -> 2019/2120 out to 4 to 5 years in advance.

TSD – A new opportunity for smarter maintenance

Photo of a typical shallow shear deformation occupying about 1 m length in LWP. When averaged over 10 m, the characteristic is lost in the diluted signal. In NZ pavements with typically 0.7 - 2 mm deflection, it would be practical to specify TSD sampling intervals of 2 or 3 metres rather then 10 m, greatly enhancing the 3-5+ year forward planning for maintenance by predicting the total length of digouts and their locations several years before they are visually detectable. Ongoing digouts vs AWT.

Improving the reliability of TSD interpretation

Key is contractor input based on long term experience and close familiarity with the network.

Feedback can be difficult to extract, so can the ease of inputs from others be simplified.

Smartphone – gestures on-road with GPS.

Feedback: Validation and Calibration of Model

On-road viewing of pavement life and other parameters now with capability to provide instant feedback.

PaveState smartphone app

2013 version now upgraded to display structural capacity, future distress mechanisms, remaining life, drainage priorities, HCV damage and rehabilitation quantities/costs.

Recent innovations with PaveState include tools for faster collection of data in the field: visual distress and other features can be logged using gestures (screen swipes) and/or speech recognition tagged to the specific chainage and lane. During examination of terminally distressed sites these greatly facilitate the otherwise time consuming task of validation and calibration of a mechanistic model.

PaveState Application

Data Source – Cell colour depending on data source ie FWD, TSD etc.

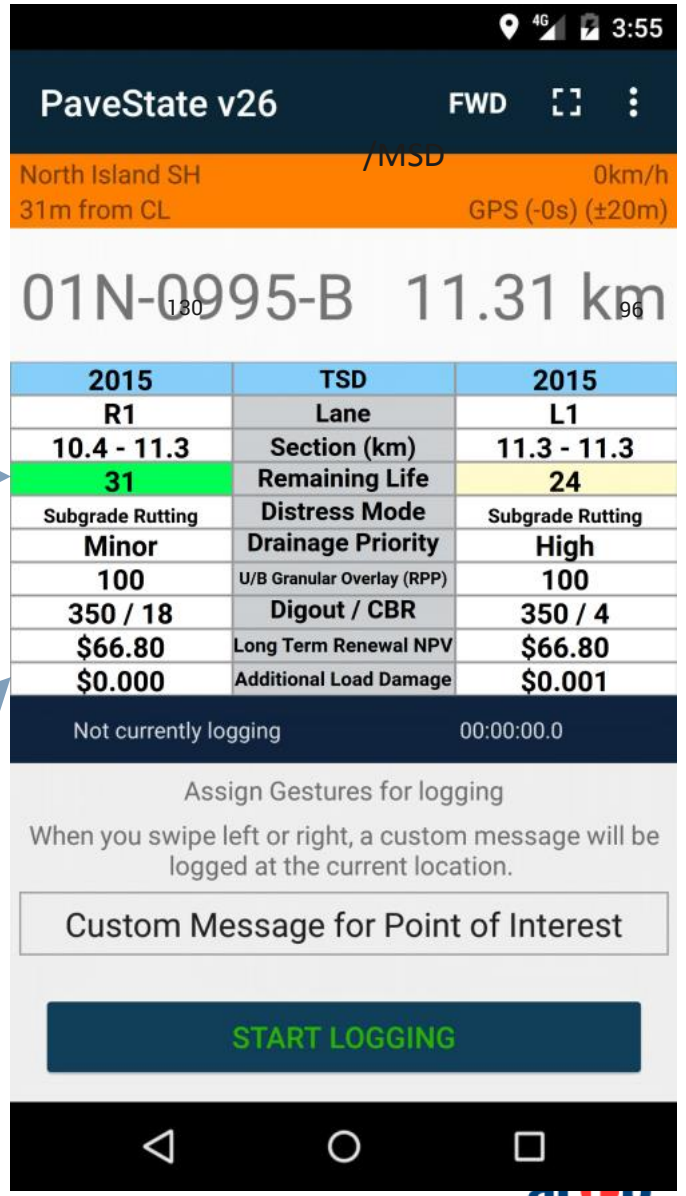
Start and end chainages of structural treatment length (STL)

Remaining Life of STL– Highlighted colours change with GPS location, relating to life for easy visual inspection.

Forward work programme (FWP) budget:
$/lane-km/per annum (NPV)

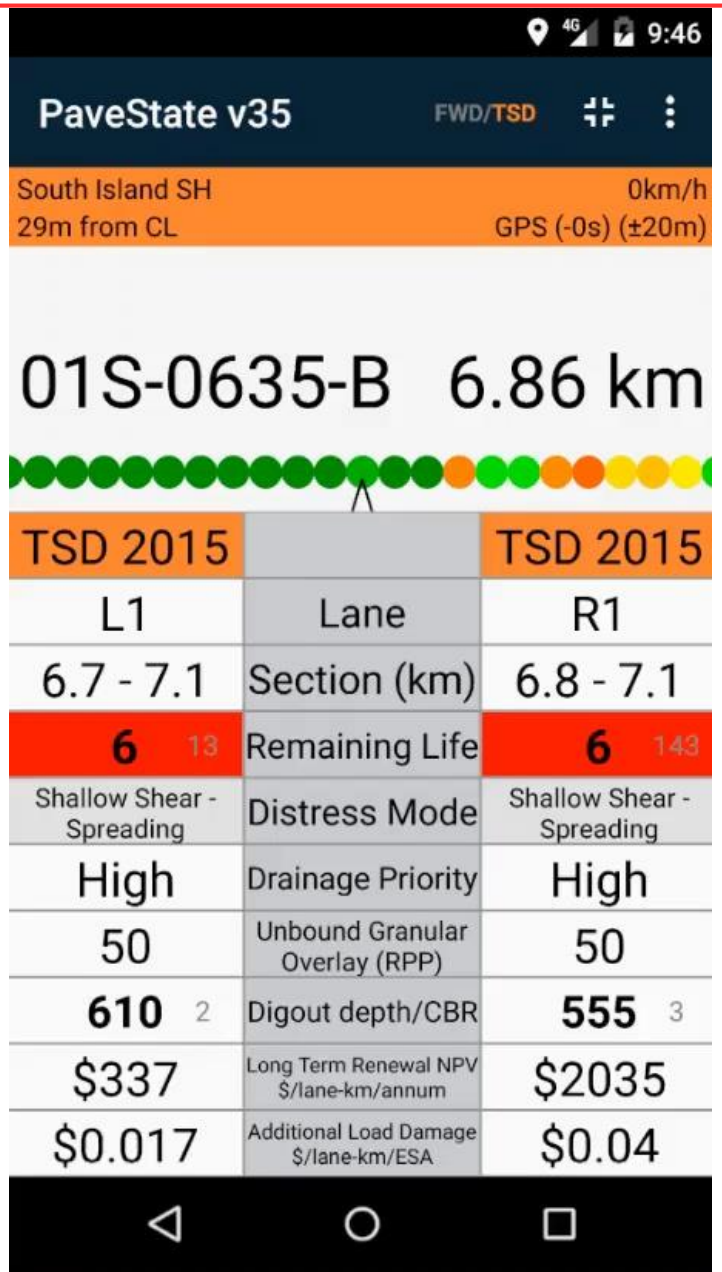
For additional heavy vehicle wear:
$/lane-km/ESA

NPV $ based on local unit rates and number of years until renewal is required.



PaveState Application

Displayed remaining life is a specific characteristic percentile (eg 10%ile) for each treatment length. However, individual 10m values can also be viewed →



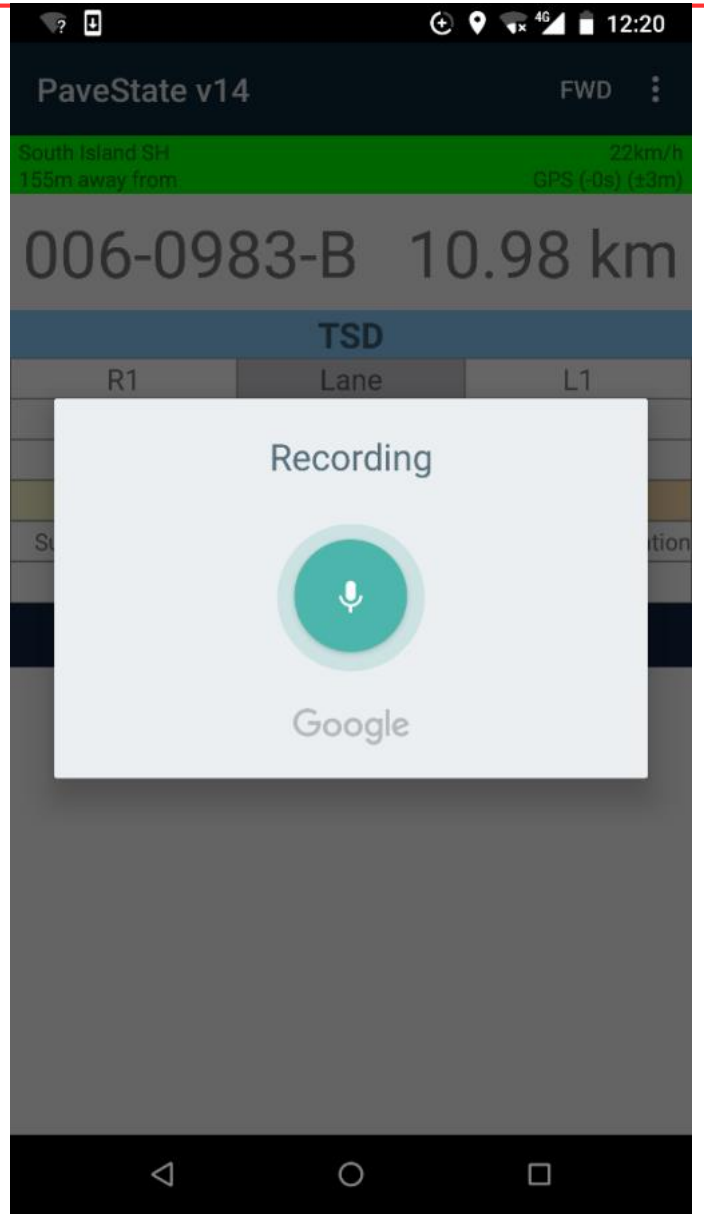
PaveState Application

Voice recording – enables user to invoke Google speech recognition using a pre-defined set of key words to record features of interest tagged for location while travelling.

Uploaded, these are used in routines for validation, calibration and QA checks.

Gestures – can be used alternatively with specific directions of swipe signifying modes of distress, their severity or new locations for TL section breaks.

The end result for users is the effortless provision of their feedback using reality checks: the key ingredient allowing continuous improvement of the mechanistic model and increasing reliability of the model and subsequent FWP.



Closure: Applications of TSD data > ongoing improvement

1. Determining extents for each structurally homogeneous sub-section (STL)
2. Potential for improvement from subsurface drainage, and effects on FWP
3. Remaining Service Life (from NPV) &
4. Terminal Distress Mode ->
5. Most appropriate form of rehabilitation ->
6. Budget $ per treatment length (NPV) or $/ESA/lane km
7. Priorities and Optimised Forward Work Programme (integrating the effects of subsurface drainage, structural maintenance and eventual rehabilitation) ->
8. Total budget for FWP - Cumulative (25 year) Annual Expenditure

Goal 80/20 but >80% - > Feedback

Potential: (TSD specific)

Economics for ongoing heavy (structural) maintenance vs wider rehabilitation ($)

Thin seal surfaced unbound pavement: 1-2%/year 0.5-1%/year