The safe system approach to road safety works on the principle that it is not acceptable for a road user to be killed or seriously injured if they are involved in a crash. The safe system approach also acknowledges that road users are fallible and will continue to make mistakes. Integral to the safe system approach are safer roads and roadsides and understanding crashes and risks. This presentation examines the contribution of three key pavement surface characteristics to crash risk, these being wheelpath roughness, rutting and change in crossfall (i.e. rate-of-rotation).

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Presentation Outline

- Need for Research
- Statistical Modelling Approach
- Derived Crash Rate Relationships
- Key Findings

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Need for Research

- How to interpret road surface condition and geometry data acquired during annual high speed surveys of NZ's sealed state highway network to identify locations where the safety of the travelling public could be compromised.
- Derivation of robust crash risk relationships for use in setting cost - effective maintenance intervention triggers.

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Methodology (1)

- Poisson regression model relating reported injury road crash rates to road condition and road geometry revisited to focus on road parameters of interest.
- Databases used comprised:
  - NZ Transport Agency's *Road Assessment and Maintenance Management (*RAMM*)* database, which contained information on carriageway, road condition and road geometry
  - The Crash Analysis System (CAS) managed by the NZ Transport Agency, which is NZ's primary tool for capturing information on where, when and how road crashes occur. (Over period 2011-2016 131 fatals, 593 serious injury, 2335 minor injury and 6645 non-injury crashes per annum on SH network)
  - Hourly rainfall data from 121 meteorological stations administered by the National Institute of Water and Atmospheric Research (NIWA)

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Methodology (2)

- Analysis would not be possible without the road condition and road geometry data acquired since 1998 as part of the annual SCRIM+ surveys of NZ's state highway network

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Methodology (3)

Parameters acquired during SCRIM+ surveys:

- 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)
  - Skid Resistance (SCRIM Coeff.) (10m intervals)

One million data points on each side of the road for each year!

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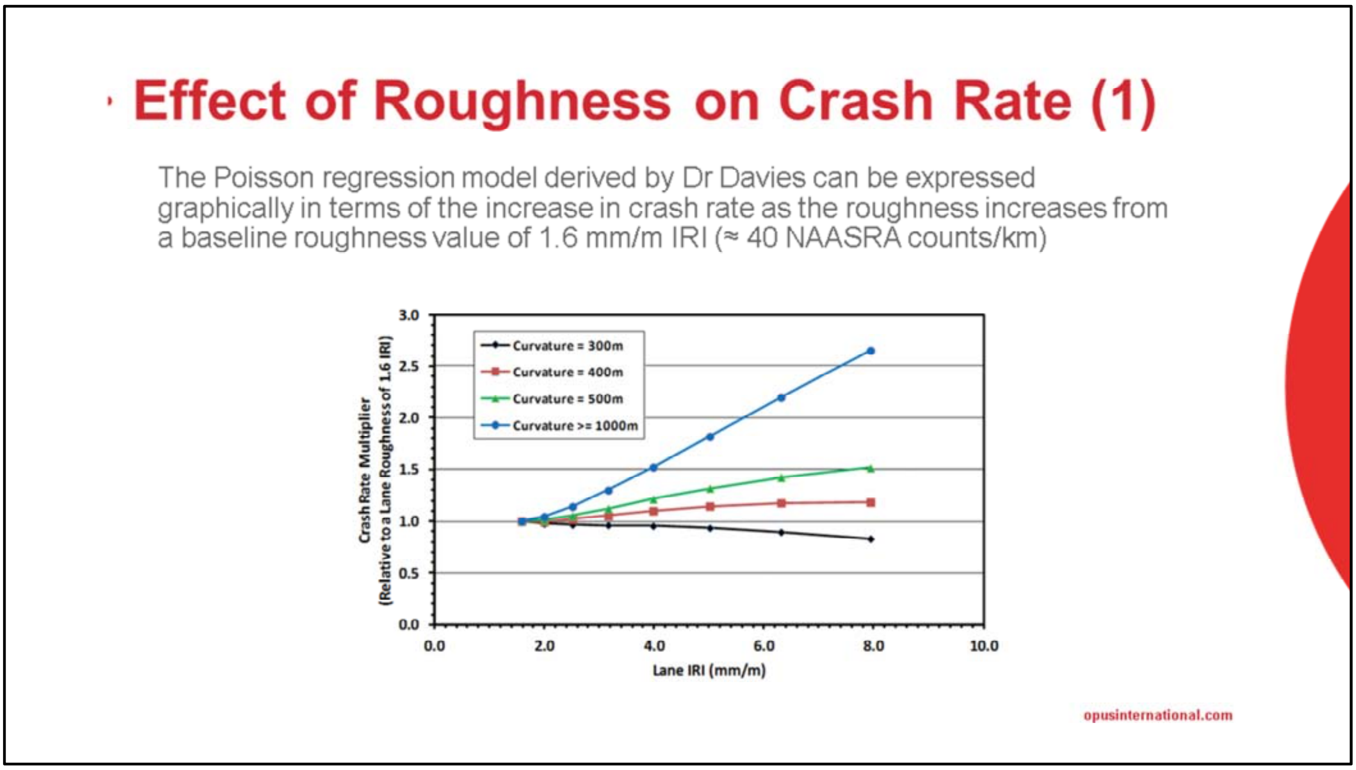

Figure shows, for example, that for roads with a horizontal curvature of radius greater than or equal to 1000m, a 40% reduction in the IRI roughness from 5mm/m to 3mm/m will result in a reduction in the crash rate of about 28%. However, if the horizontal curvature is tightened to 400m, this 40% reduction in road surface roughness will result in a reduction in the crash rate of only 8%.

Effect of Roughness on Crash Rate (2)

The key points to note are as follows:

- There is no reduction in crash rate for reductions in IRI roughness below 2 IRI mm/m (which corresponds to a lane roughness of about 50 NAASRA counts/km).
- Roughness has an increasing detrimental impact on crash rate as horizontal curvature increases.
- For curves with horizontal curvature less than 400m i.e. tight to moderate curves, increasing roughness decreases crash rate. A possible explanation for this result is that previous research by Opus has shown the speed vehicles are driven around curves to be influenced by the lane roughness, the speed decreasing with increasing roughness.

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Effect of Rutting on Crash Rate (1)

- The aim of the statistical studies was to find relationships between rut depth and crash rates, particularly for rut depths in the range 10mm-30mm.
- However very little of the SH network has rut depths that fall into this range.
- Analysis, therefore, limited to rut depths in the range of 0mm-20mm.

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Effect of Rutting on Crash Rate (2)

- Following plots show how the crash rate derived from the Poisson regression model is affected by increasing rut depth
- Plotted crash rates are in crashes per 100 million vehicle kilometres travelled.
- Error bounds show two standard deviations (roughly 95% confidence interval)

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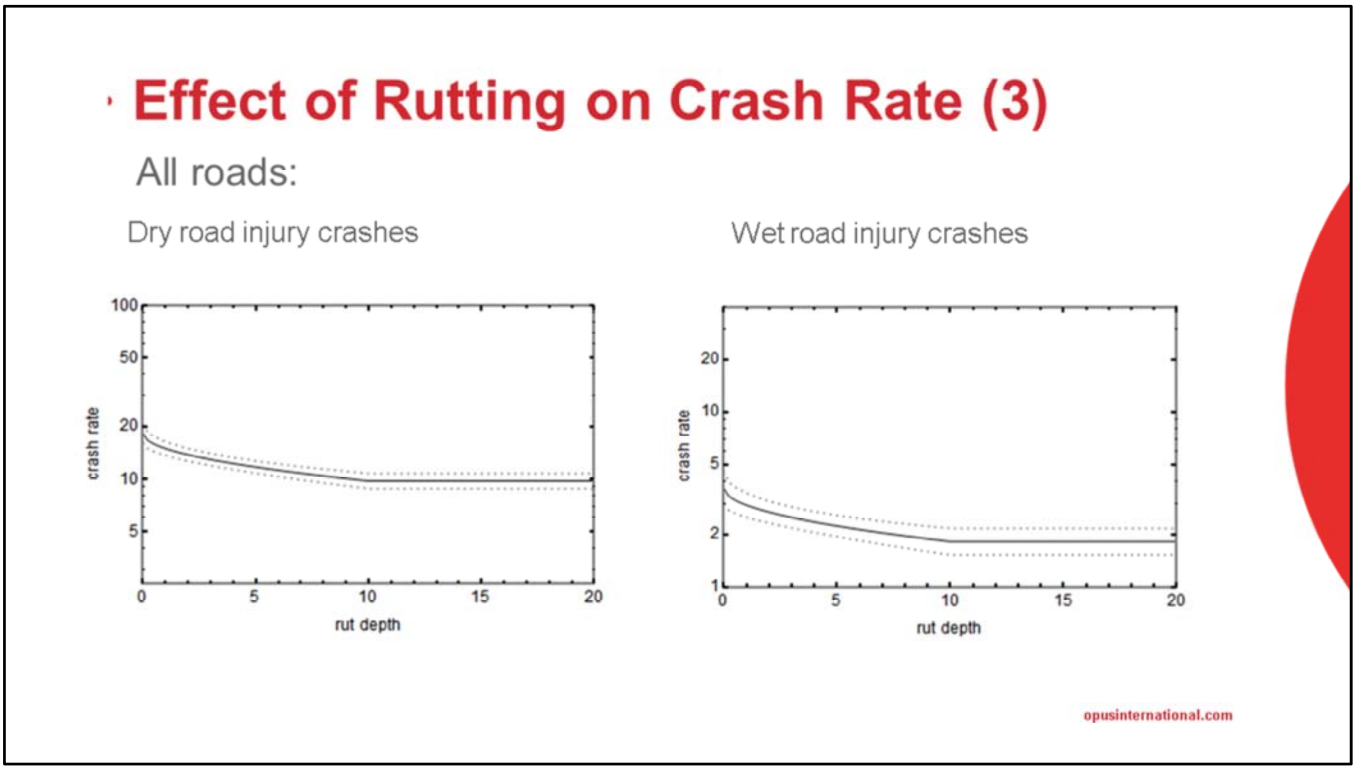
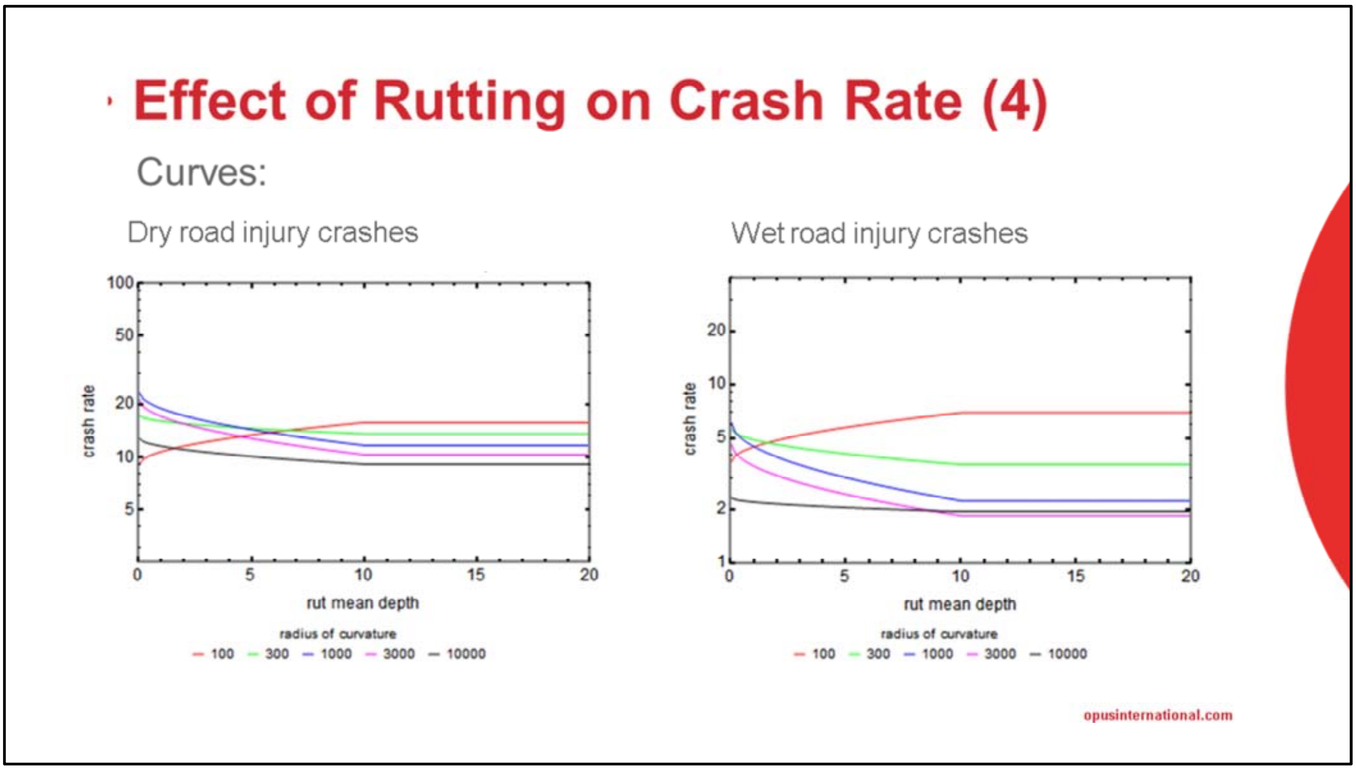


The crash rate decreases as mean rut depth increases.

The wet road crash rates shown are much smaller than for the dry road crash rates. This is because we do not know what percentage of the time the road is wet and cannot adjust for this.

Plots are for a default radius of curvature of 5000. The effect changes for different curvatures.



The crash rate reduces as rut depth increases for curves with a radius of curvature in the range 1000m to 3000m. The effect is weaker for curves outside this range. The graphs suggest that crash rates increase with rut depth for very curved roads, but this might be partly due to the way the predictor variables are defined.

Effect of Rate of Rotation on Crash Rate (1)

What is rate-of-rotation?

- Rate-of-rotation, or "warp factor" is a measure of the variation in crossfall of a surface.
- It typically relates to a change in crossfall from that of a normal straight road to that chosen for a curve to enhance forces assisting the vehicle to stay on the road.
- Rate-of-rotation limits used in NZ for comfort are:
  - 0.035 rad/s (3.5%/s) for constrained two-lane two-way roads, design speed ≤ 70 km/h
  - 0.025 rad/s (2.5%/s) for unconstrained, two-lane two-way roads
  - 0.02 rad/s (2.0%/s) for divided roads

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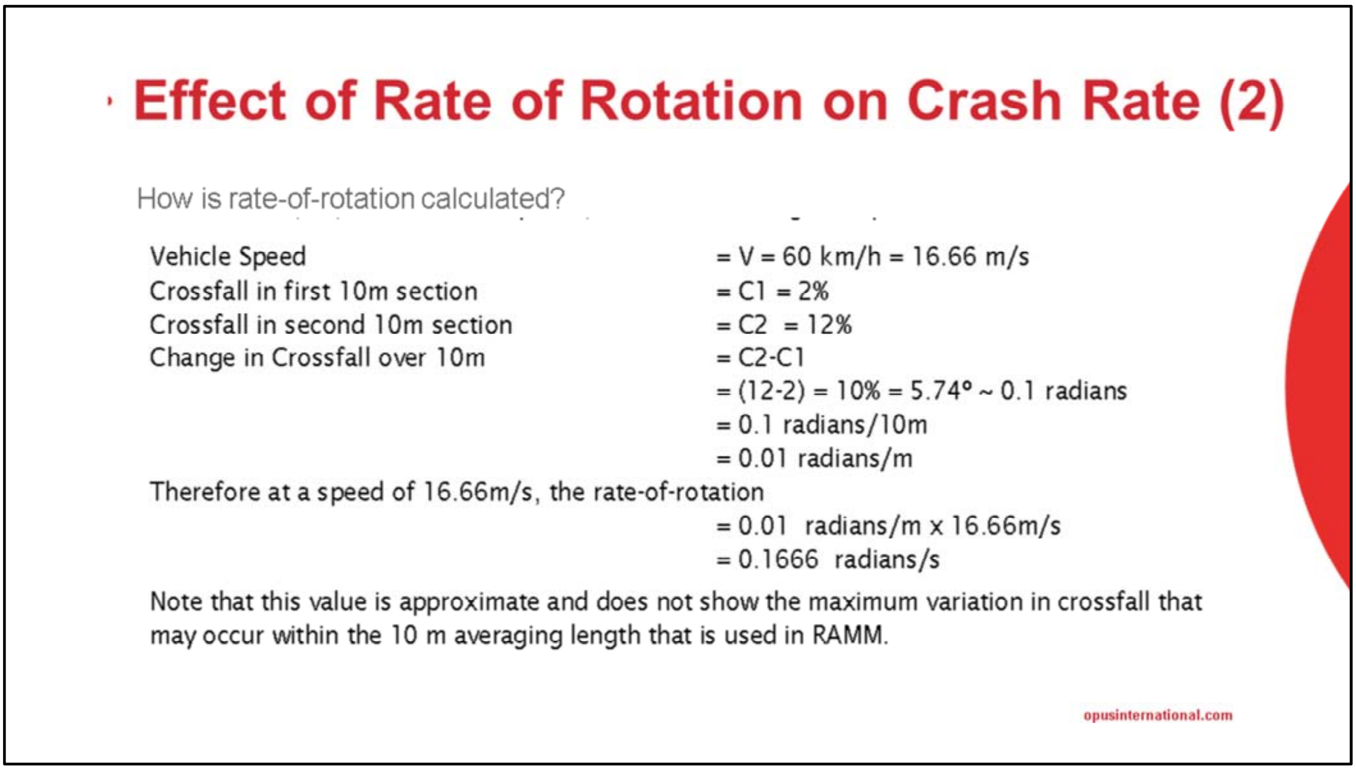
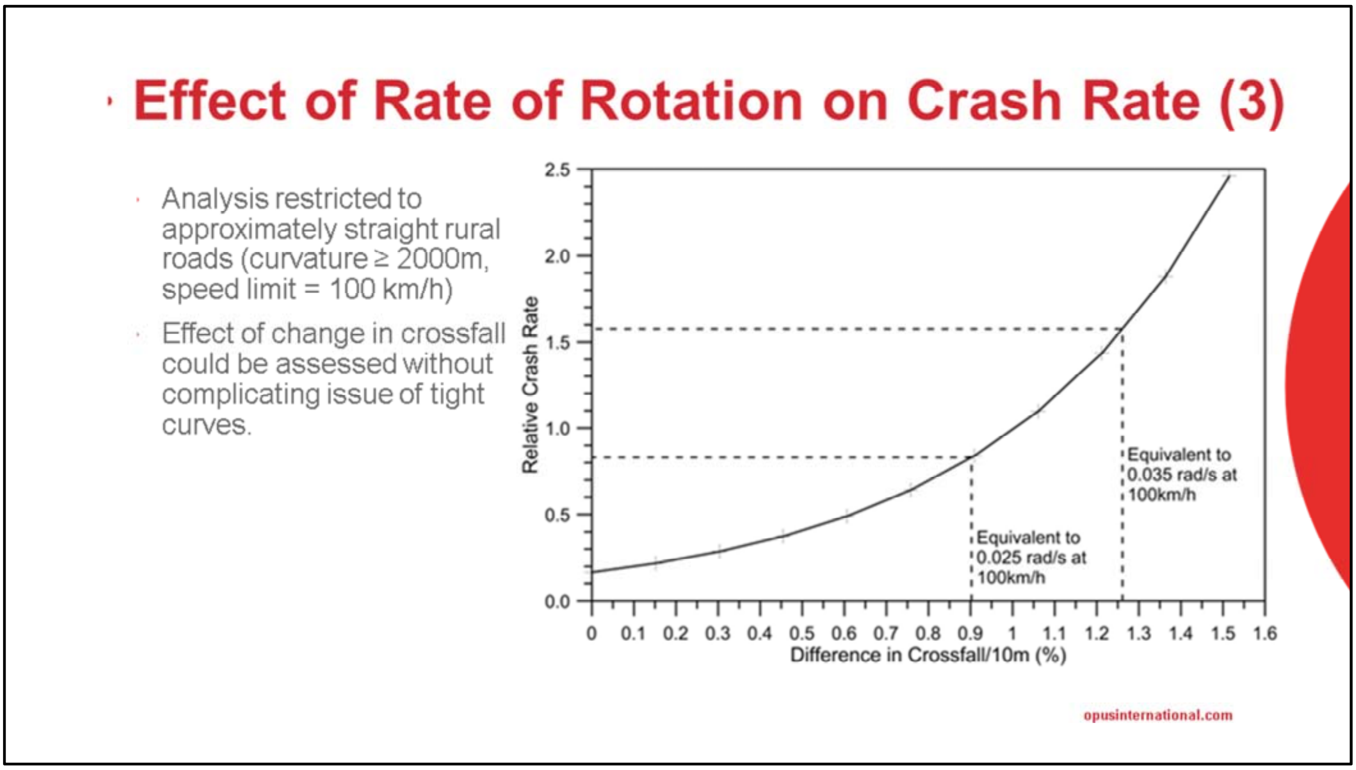


The 10 m average crossfall vales in RAMM are given in terms of a percentage value (~~%)~~%), e.g. 10% crossfall equates to a 1:10 slope from the centreline to the edge of the lane. An approximate rate-of-rotation for a vehicle travelling at a particular speed can be derived by relating the variation in the crossfall (roll) to the vehicle speeds, as in the example.



This analysis showed that changes in crossfall, and hence the rate-of-rotation, do have a statistically significant effect on the crash rate. The relationship is shown in the plot. This shows the relative change in crash rate against the change in crossfall for each 10 m road section. Also shown on the plot are the changes in crossfall that correspond to the 0.025 rad/s and 0.035 rad/s threshold limits, for a vehicle travelling at 100 km/h.

This figure shows that varying the change in crossfall per 10m between the two threshold limits for rate-of-rotation corresponds to slightly less than a doubling in the crash rate. It also shows that there does not appear to be a critical threshold value for rate-of-rotation (change in crossfall) above which the relative crash rate increases more dramatically.

Key Findings (1)

- ***Roughness***
  - The effect of roughness on crash risk depends on curvature, the effect being strongest on curves with radii of curvature in the range 500 to 5000m.
  - There is no strong evidence of a critical level of roughness above which crash risk increases significantly. Rather, crash risk continues to increase with increasing roughness.
  - Repeating the analysis using only serious/fatal crashes produced results very similar to those for all injury crashes.

Key Findings (2)

- ***Rutting***
  - Very little of the SH network has rut depths in the 10mm-30mm range.
  - Crash rates decrease slightly as rut depth increases over the normal range of rut depths, particularly for dry road crashes. (A possible explanation might me that drivers exercise greater caution when traversing ruts than when traversing smooth pavement surfaces – more so in dry conditions when ruts are visible and less so in wet conditions when ruts may become hidden beneath ponded water.)
  - Suggestion that crash rates increase with rut depth for very curved roads, but this may be partly due to the way the predictor variables are defined.

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Key Findings (3)

- ***Rate-of-Rotation***
  - Statistical analysis of crash and geometry data for the SH network showed that, as expected, changes in crossfall are strongly correlated with horizontal curvature because of the need to deal with radial forces on cornering vehicles.
  - Removing curvature as a variable showed that rate-of-rotation remained a significant predictor of crash rate.
  - It also showed that there did not appear to be a critical rate-of-rotation above which crash rates increase significantly.

More Information

Source reports can be downloaded from the NZTA website (https://www.nzta.govt.nz)

- Central Laboratories Report 12-529B39 "Quantification of Safety Benefits Resulting from Road Smoothing"
- NZ Transport Agency Research Report 545 "The Relationship between Crash rate and Rutting"
- NZ Transport Agency Research Report 456 "Improved Rate-of-Rotation Design Limits"
- NZ Transport Agency Research Report 477 "Modelling Crash Risk on the New Zealand State Highway Network"

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