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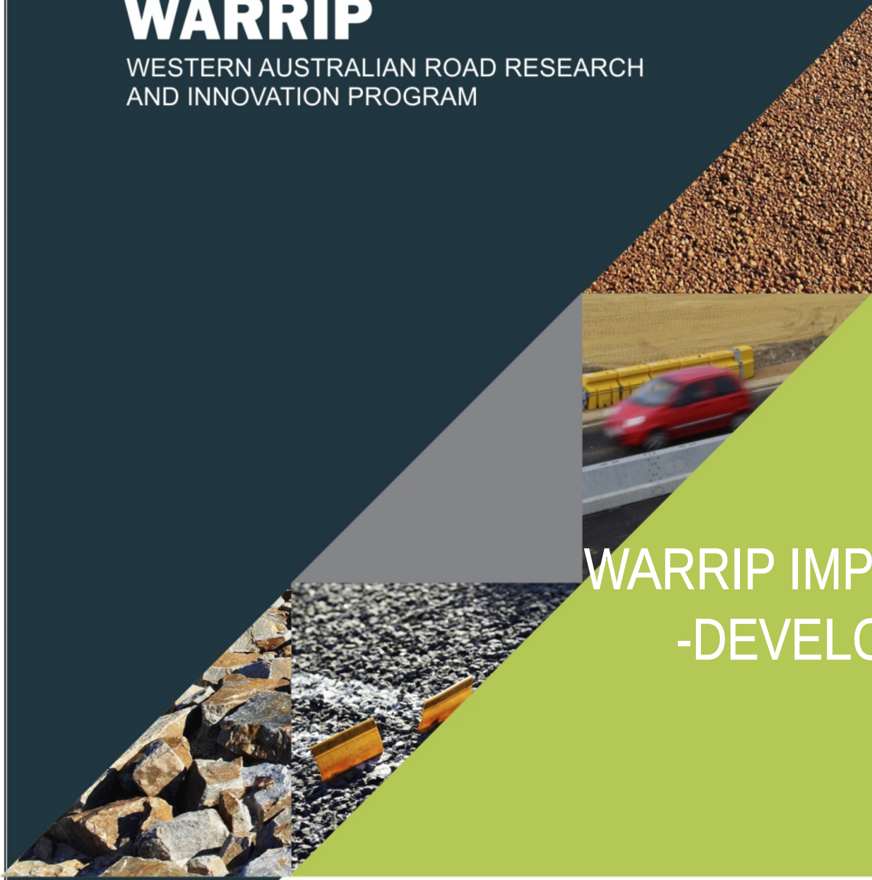

WARRIP IMPROVED DECISION MAKING (IDM) STAGE 3 -DEVELOPMENT OF RUTTING MODEL FOR WA PAVEMENTS

AN INITIATIVE BY:

Acknowledgement of Country

The Government of Western Australia acknowledges the traditional custodians throughout Western Australia and their continuing connection to the land, waters and community. We pay our respects to all members of the Aboriginal communities and their cultures; and to Elders both past and present.

Housekeeping

Michelle Ciantar
Professional - Communications
National Transport Research Organisation
(NTRO/ARRB)

- Webinar is 60 mins
- Includes Question Time of 10 mins
  - Please take note of the slide number for any questions that come up during the presentation and our presenters can refer to them at the end.

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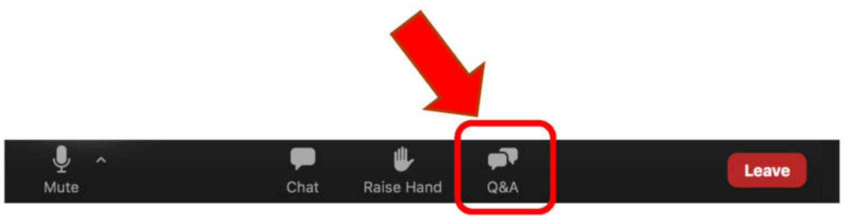
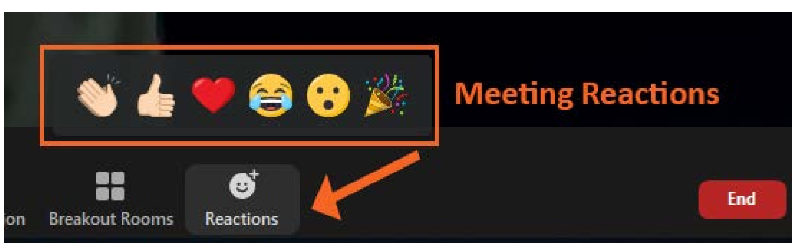
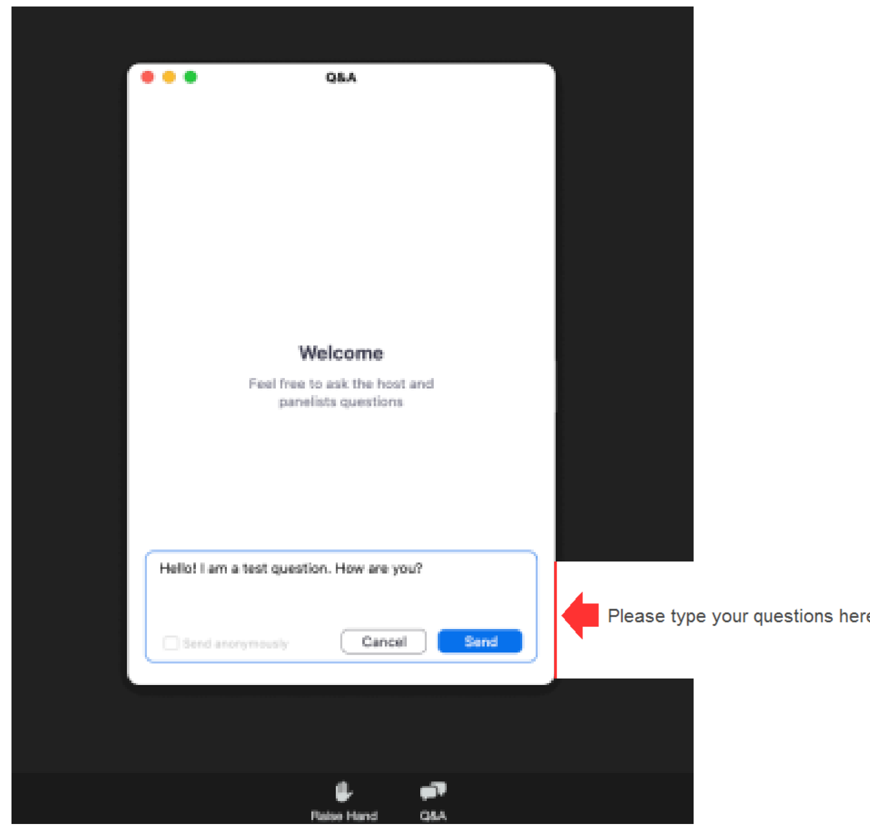
Zoom Webinar Functions

Click on the “Q&A” button at the bottom of your screen. You may need to “hover” or click on your screen for that option to appear.



Click the “Reactions” button and select the **“Raise Hand”** option from the menu. Once you finish speaking, click the “Reactions” button again and click the **“Lower Hand”** option to lower your hand.





Presenters

Ranita Sen
Principal Professional
Engineer - Asset Performance
National Transport Research Organisation (NTRO/ARRB)

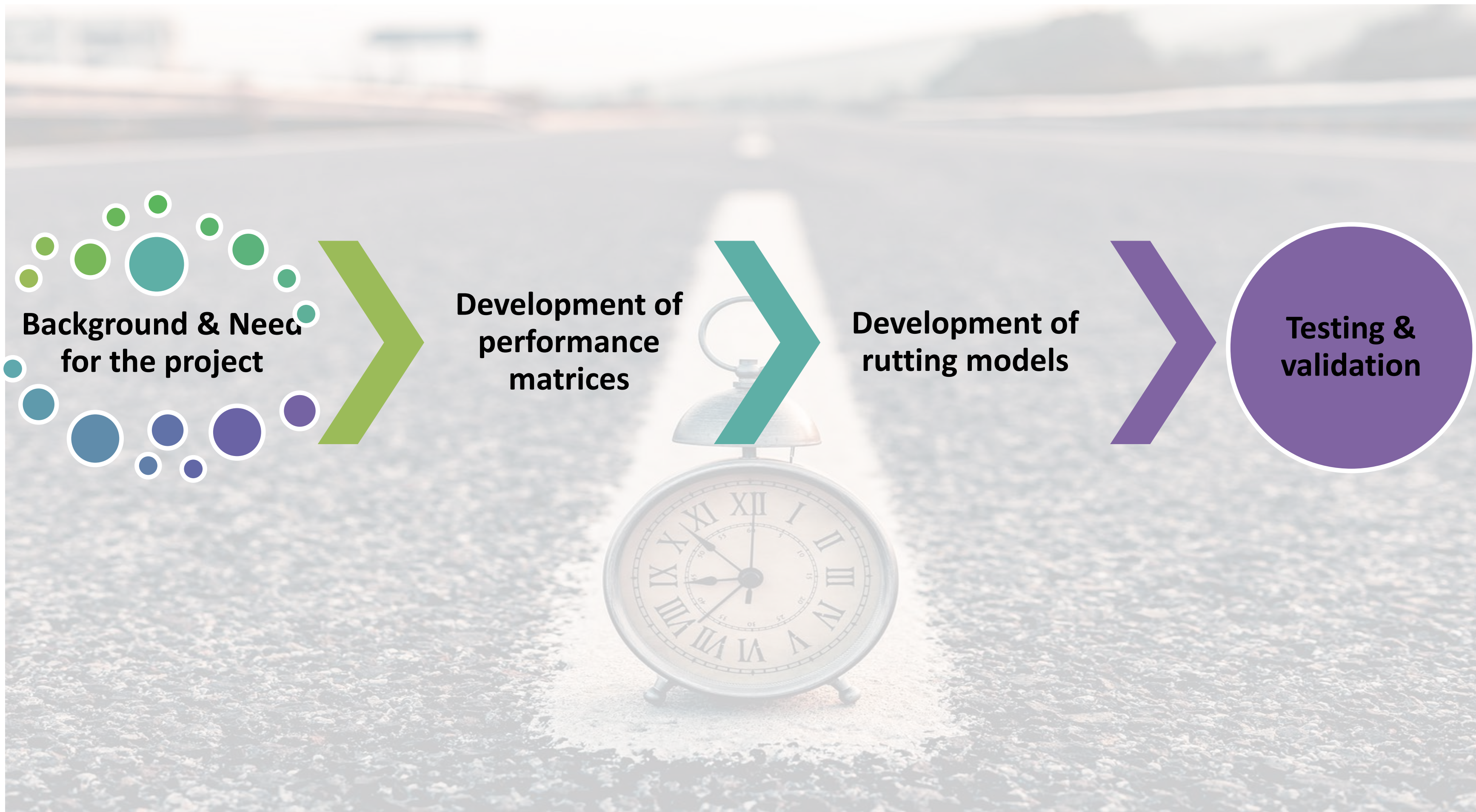
Dr. Tim Martin
Chief Technology Leader - Asset Performance
National Transport Research Organisation (NTRO/ARRB)

Qindong Li
Asset Management Modelling & Analytics Manager -
Main Roads WA

About WARRIP

- A collaborative research initiative between Main Roads WA & the National Transport Research Organisation (NTRO/ARRB)
- WARRIP aims to deliver innovative, sustainable, and cost-saving solutions for road infrastructure projects throughout Western Australia.
- Our research program covers areas in pavements, asset management, road safety, sustainability and structures.
- For more information please visit our website: https://warrip.com.au/

Webinar Outline



Background & Needs for the Project

MRWA Maintenance Challenges

- Largest geographically spread road jurisdiction in the world
  - Covering 2.5 million square kilometres
  - 19,000 km state network
  - Pavement & surfacing assets valued over $10 billion
- Limited fund vs increased community expectation
- More government scrutiny on funding need
- An aging work force
- In house delivery of maintenance.

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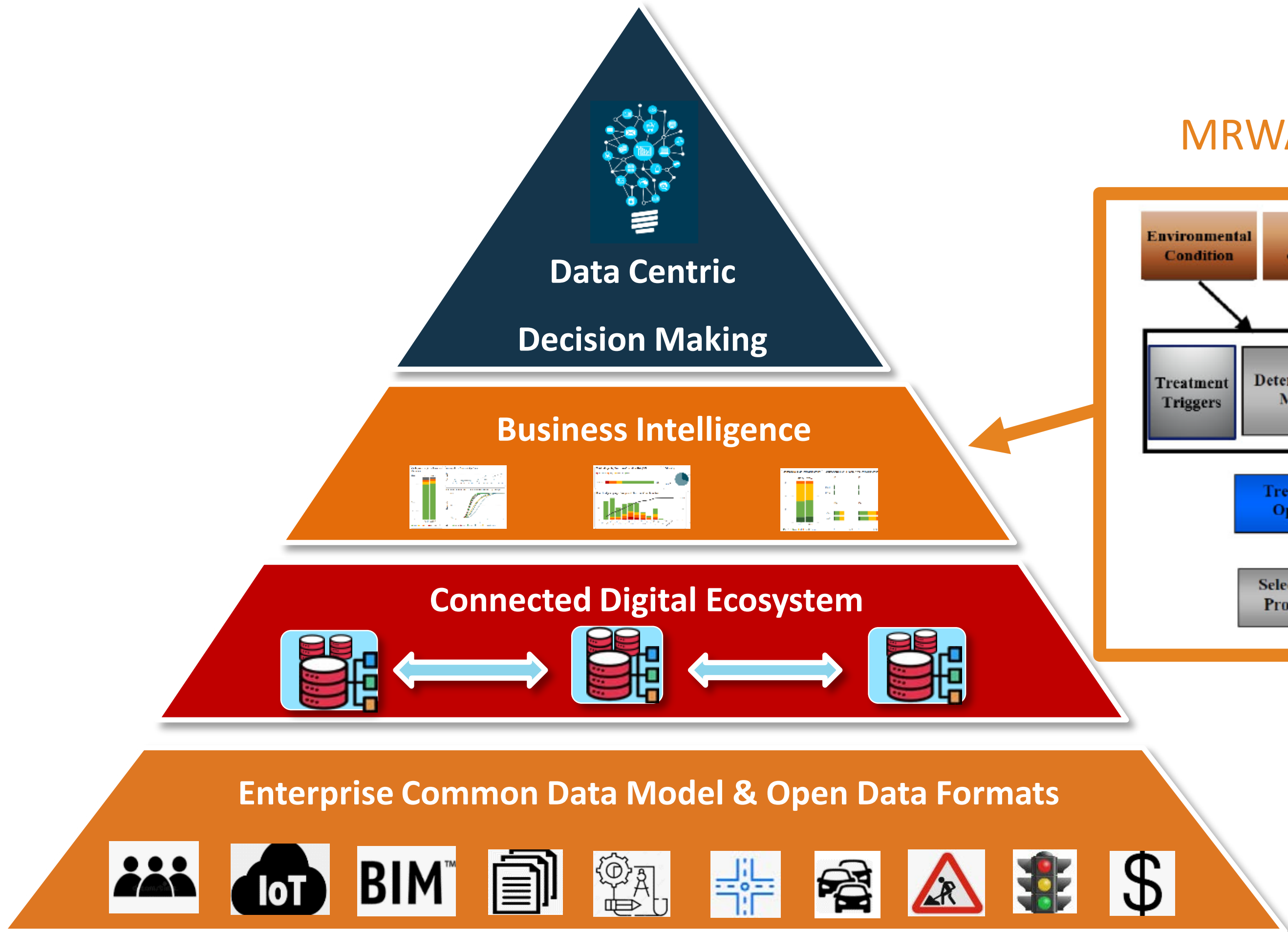
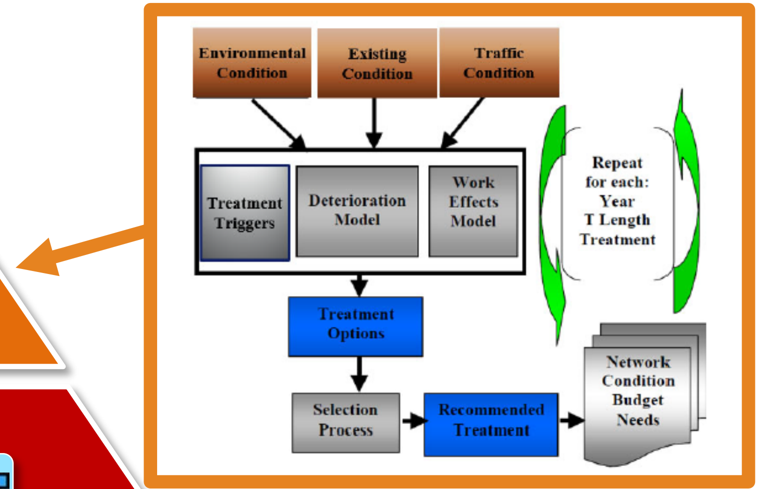
Solution: Working Smarter with Data



MRWA dTIMS Model



WARRIP Improved Decision Making

- Stage 1 Work
  - Compared various modelling approaches
  - Recommended to validate MRWA deterioration models
  - Recommended to use Work Program to validate treatment selection decision tree.

- Stage 2 Work
  - Used MRWA Rehab Program to identify significant predictors
  - Most significant predictors: max rut, max roughness and max deflection
  - A rehab formula for identifying pavement repair and rehab.

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WARRIP Improved Decision Making

Aim of the IDM multi- stage project

- Improve MRWA's understanding of the **performance of its pavement** network using Traffic Speed Deflectometer data
- Enhance MRWA decision making through more **accurate performance prediction and site and treatment selection**

Objectives of the current stage - IDM Stage 3

- Development of performance matrices for **rutting progression across WA regions**
- Formulation of **rutting progression model** based on WA pavement conditions

Outcome of the current stage

Network level total rut progression model. Validated against observed rutting.

IDM Stage 3- Topics Covered

- Rutting performance matrices for WA road network
- Developed of rutting progression model(s)
- Testing and validation of the developed model (s)
- Scope for further development.

Development of Performance Matrices

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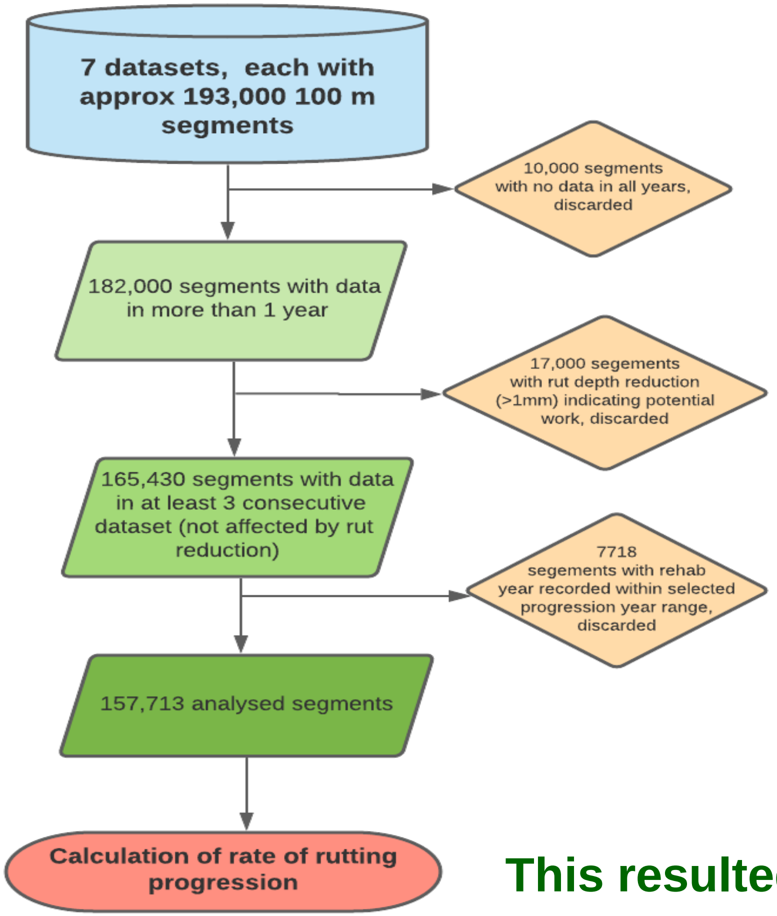
Segment Selection

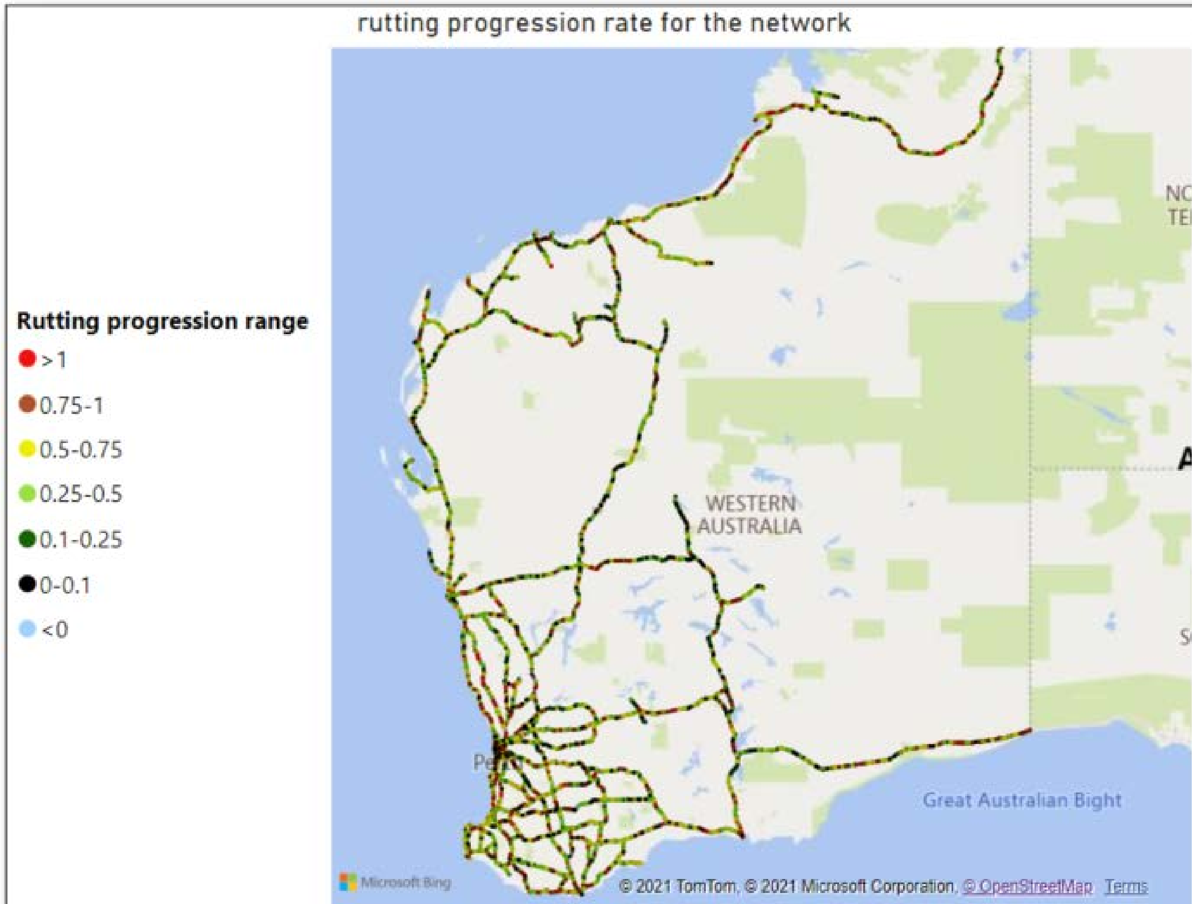


Region	Length from supplied data (km)	Analysed length (km)	% length
Great Southern	1632	1359.25	83%
South West	1861.66	1630.3	88%
Goldfields Esperance	2489.31	2106.31	85%
Kimberley	2133.09	1417.98	66%
Metro	1386.52	1064.23	77%
Wheatbelt	3022.18	2585.88	86%
Pilbara	2989.26	2327.64	78%
Mid West Gascoyne	3727.07	3245.35	87%

This resulted in around 157,713 filtered segments.

Rut progression rates calculated for the above segments.

Rut Progression Rates for the Network



Rutting Range	Segment count	% of total segments
0.25-0.5	48844	30.97%
0.1-0.25	30545	19.36%
0.5-0.75	25922	16.43%
>1	21379	13.55%
0.75-1	14586	9.25%
0-0.1	10389	6.59%
<0	6072	3.85%
Total	**157737**	**100.00%**

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Average Rut Progression for Regions

Region_Name	Average rut progression
Great Sourthern	0.586
South West	0.567
Goldfields Esperence	0.489
Kimberley	0.693
Metro	0.433
Pilbara	0.468
Wheatbelt	0.517
Mid West Gascoyne	0.521

% length in rut progression ranges for Regions

Row Labels	<0	0-0.1	0.1-0.25	0.25-0.5	0.5-0.75	0.75-1	>1
Great Sourthern	3.46%	5.54%	16.49%	28.71%	18.68%	11.12%	16.01%
South West	4.14%	5.78%	17.56%	29.89%	17.62%	9.66%	15.35%
Goldfields Esperence	4.95%	10.78%	23.60%	25.70%	13.74%	8.36%	12.86%
Kimberley	2.02%	2.98%	11.03%	28.75%	18.33%	12.12%	24.76%
Metro	7.20%	8.53%	21.27%	31.60%	15.61%	7.11%	8.67%
Pilbara	2.95%	5.64%	21.46%	36.57%	15.62%	8.28%	9.48%
Wheatbelt	4.51%	7.80%	21.77%	29.13%	15.47%	8.40%	12.92%
Mid West Gascoyne	2.92%	5.35%	18.32%	34.03%	17.46%	9.67%	12.24%

- Average rut progression ranges from 0.4-0.7 mm/year
- Almost 1/3rd of the length in each region has rut progression between 0.25-0.5 mm/year
- Nearly 10% length in each region has rut progression >1 mm/year
- Kimberley has around 25% length with rut progression > 1 mm/year.

Average Rut Progression for AADT Bands

AADT_Range	Average rut progression
<500	0.516
500-1500	0.551
1500-3000	0.555
3000-5000	0.578
5000-10000	0.571
>10000	0.426

% length in rut progression range for different AADT bands

AADT_Range	<0	0-0.1	0.1-0.25	0.25-0.5	0.5-0.75	0.75-1	>1
<500	3.47%	6.91%	19.73%	31.77%	15.78%	9.13%	13.21%
500-1500	3.38%	5.78%	19.06%	30.30%	17.58%	9.69%	14.22%
1500-3000	4.77%	6.44%	18.59%	29.52%	16.19%	9.32%	15.17%
3000-5000	5.30%	6.55%	17.75%	26.85%	16.57%	10.54%	16.44%
5000-10000	5.37%	6.10%	16.16%	29.49%	17.11%	9.57%	16.20%
>10000	6.92%	8.33%	21.43%	31.83%	16.45%	7.12%	7.93%

- In general, higher AADT associated with lower avg rut progression
- Almost 30% of length in each AADT band has rutting progression at 0.25-0.5 mm/year
- With increase in AADT, higher % length in lower rutting rate band (towards the left) is observed and vice versa – aligns with design standards.

Rut Progression for Link Category

Link_Cat	Average rut progression
AW	0.560
BW	0.554
CW	0.498
MI	0.440

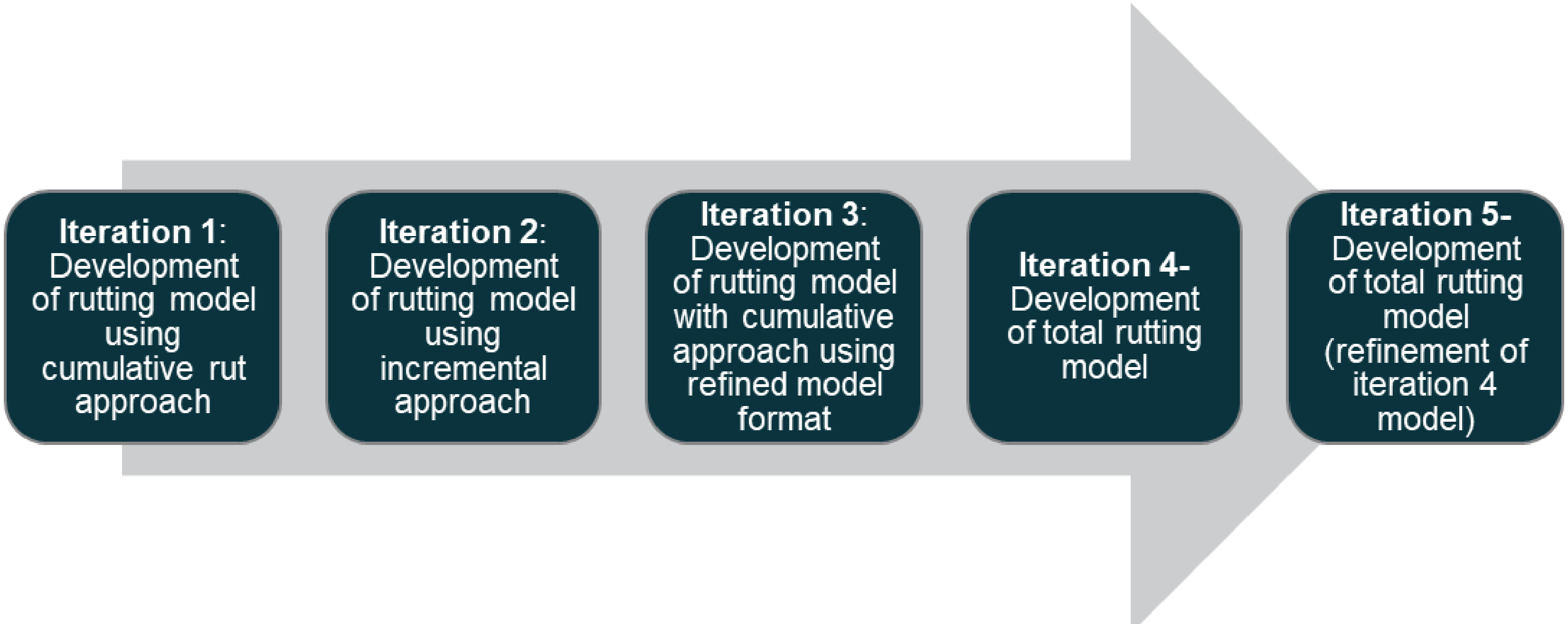
- Link Category MI has lower average rut progression rate than other link categories (Design standards).
- Most % network lengths in MI sit in lower rut progression bands compared to other link categories.
- In general, MI roads have the higher design standard as the majority is in the Metropolitan.

Findings From Performance Matrices Development

- Substantial % of the network (>10%) with rutting progression >1mm/ year
- Similar rutting distribution across the regions with higher values observed for Kimberley region
- Expected relationship between traffic and rut progression with higher traffic displaying lower average rut progression and hence higher % length in lower rut progression band
- The above observation holds true for Link categories
- MMIS spending might have a masking effect on the overall rut progression.

Development of Rutting Progression Model

Analysis Approach



Iteration 5: Development of Total Rutting Model

Data for analysis:

- Only include segments with no decrease in rutting over time.
- Total rutting data in each year was used as a data sample.
- Corresponding pavement Age, and ESAs were calculated for the data points.
- Total rutting of 1 mm at pavement age of 1 was assumed (initial densification).
- Do from TSD deflection data was used to estimate Do for all other years with collected data.
- Segments with pavement age> 40 years were discarded.

Resulted in around **78,000** segments with **371,000** data samples.

Development of Total Rutting Model

- Non-linear regression analysis using SPSS software
- Selected equation format:

  Total rutting (t) = a1+a2*(Pavementageatt-1)*(1+D0(t)*a3+(100+TMI)*a4)
- SPSS output for the selected equation format.

Parameter Estimates

Parameter	Estimate	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
a1	1.880	.006	1.869	1.892
a2	.061	.001	.060	.063
a3	.002	.000	.001	.002
a4	.012	.000	.011	.012

ANOVA[a]

Source	Sum of Squares	df	Mean Squares
Regression	8250708.573	4	2062677.143
Residual	2042006.363	371216	5.501
Uncorrected Total	10292714.94	371220	
Corrected Total	3781296.710	371219	

Dependent variable: Total Rutting (at t)[a]

a. R squared = 1 - (Residual Sum of Squares) / (Corrected Sum of Squares) = .460.

$$\mathbf{Total\ rutting\ (t)\ =\ 1.88 + 0.061(Pavementageatt - 1) * (1 + D0(t) * 0.002 + (100 + TMI) * 0.012)}$$

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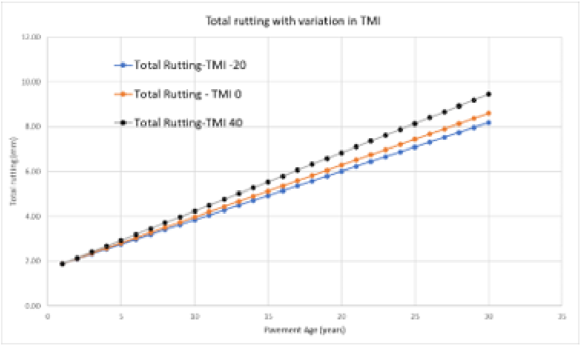
Comparison of Developed Model with Austroads (2010) Model

Total rutting model



Austroads cumulative rutting model

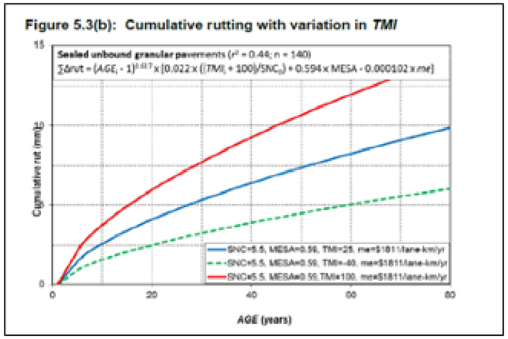
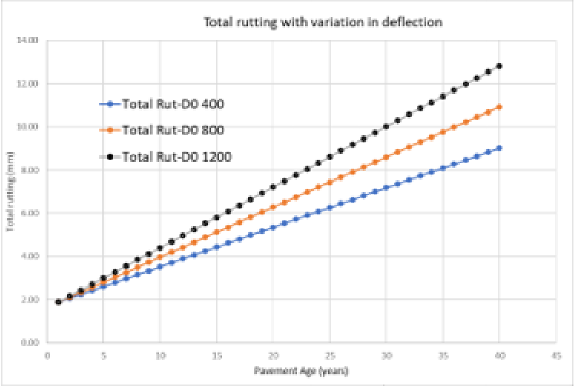
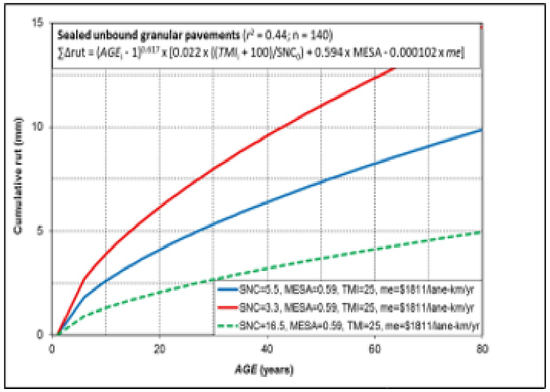


Figure 3-6 Plotting of Total rutting (using selected equation) by varying Deflection (TMI = 0) and comparison with Austroads cumulative rut model

Total rutting model



Austroads cumulative rutting model



Developed Total Rutting Model for Link Categories

Link category AW

Total rutting at t = 1.88+0.072(Pavementageatt-1)*(1+D0(t)*0.002+(100+TMI)*0.008)

Link category BW

Total rutting at t = 1.83+0.023(Pavementageatt-1)*(1+D0(t)*0.003+(100+TMI)*0.054)

Link category CW

Total rutting at t = 1.77+0.023(Pavementageatt-1)*(1+D0(t)*0.005+(100+TMI)*0.063)

Link category MI

Total rutting at t = 2.17+0.061*(Pavementageatt-1)*(1+D0(t)*0.004)

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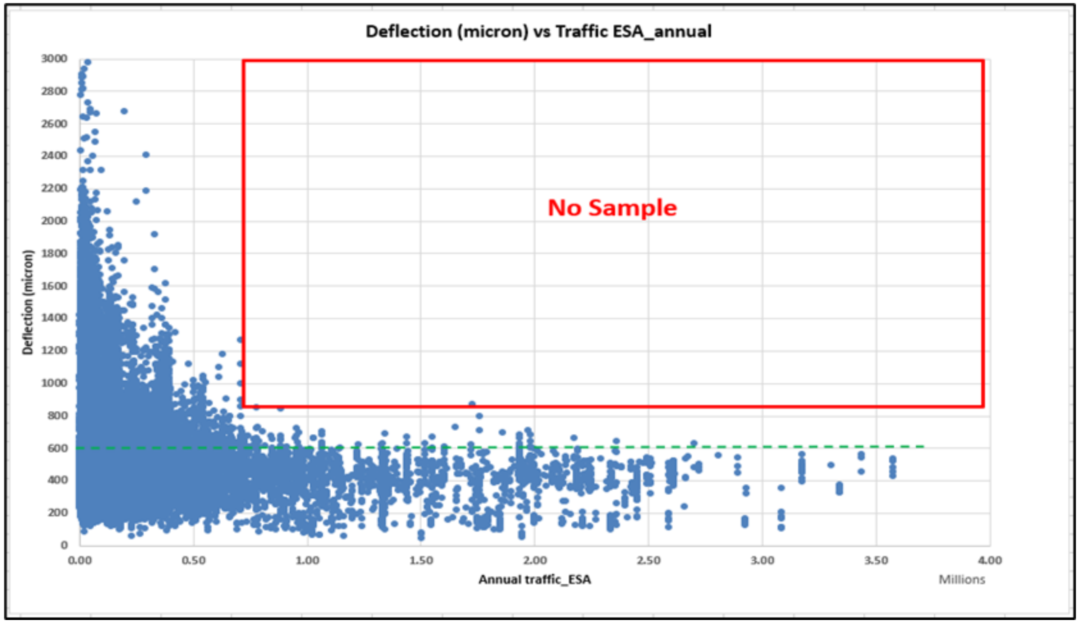
Limitations of the Developed Model



- Pavements with low strength carrying moderate to high traffic (no samples).
- Pavements with moderate strength carrying moderate to high traffic (low number of samples).

Testing and Validation of the Developed Model

Validation of the Developed Rutting Model

Initial validation conducted in 2 ways:

- Approach 1 - Using the training data set
- Approach 2 - Using the test data set

Further validation

Comparison of rutting progression rates for Goldfields Esperance and Wheatbelt region using actual observation and developed model.

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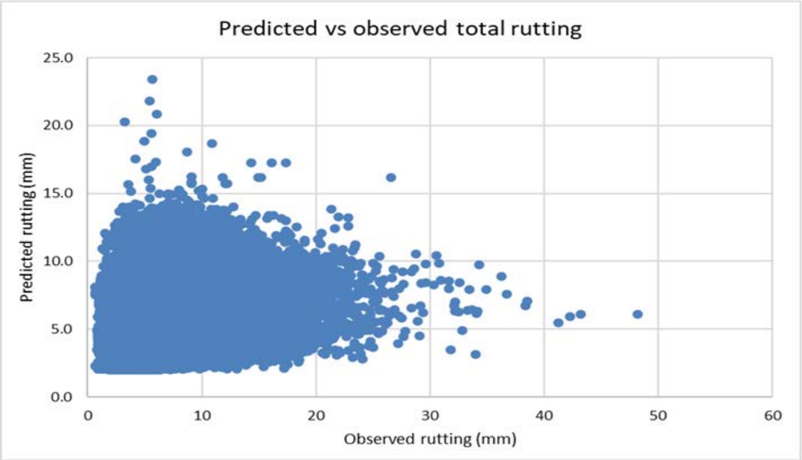
Validation of the Developed Rutting Model

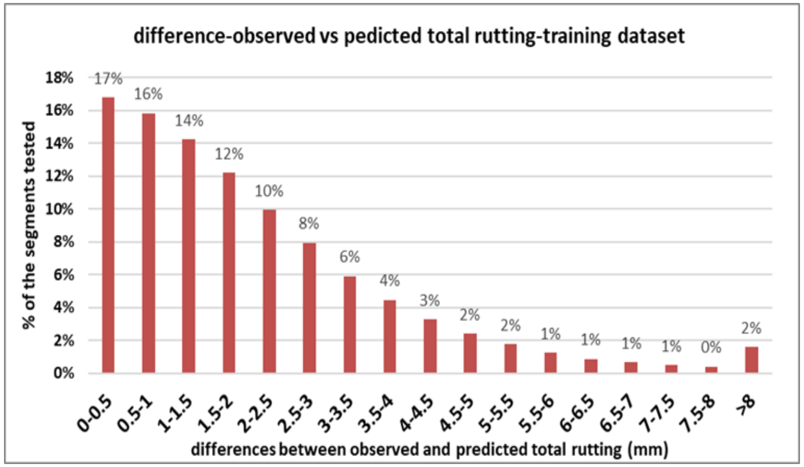
Approach 1: Using the training data set

This is the dataset used to develop the model.

- Spread in the scatter plot is expected as the predictive power of the model is moderate (adjusted R squared = 0.46)

- 33% of the analysed segments, the difference between observed and predicted values lie within 1 mm
- 7% of the segments - differences are more than 8 mm.



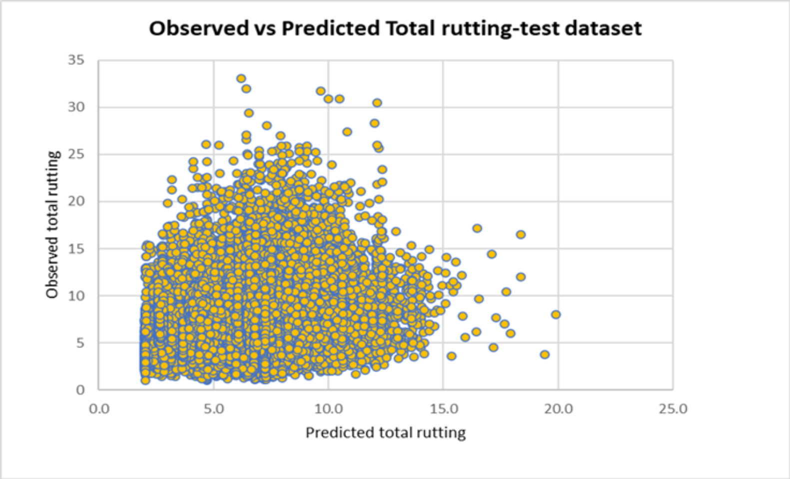


Validation of the Developed Rutting Model

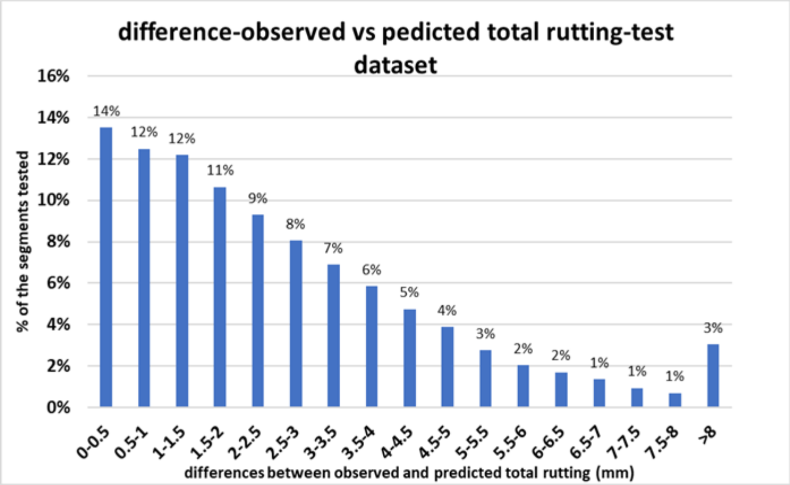
Approach 2: Using the test data set

This is the dataset not used to develop the model.

- Spread in the scatter plot is higher than the training data set, as expected



- 26% of the analysed segments, the difference between observed and predicted values lie within 1 mm.
- 3% of the segments where differences are more than 8mm.



Validation of Rut Progression for Two WA Regions

Region Name	Year	Avg Observed Total Rutting	Average Predicted Total Rutting
Goldfields Esperance	2007	6.4	5.3
	2009	6.3	5.1
	2012	5.5	4.9
	2014	6.4	5.2
	2016	5.8	5.6
	2018	8.0	6.1
	2020	8.6	6.3
Wheatbelt	2007	5.4	6.7
	2009	6.4	6.3
	2012	5.2	4.5
	2014	5.6	5.3
	2016	6.0	5.6
	2018	7.7	5.4
	2020	8.4	5.7

Predicted rate of rut progression

Region	Rutting progression rate					
	0-0.1	0.1-0.25	0.25-0.5	0.5-0.75	0.75-1	>1
Goldfields Esperance	0%	44%	55%	1%	0%	0%
Wheatbelt	0%	55%	42%	4%	0%	0%

Actual rate of rut progression

Region	Rutting progression rate					
	0-0.1	0.1-0.25	0.25-0.5	0.5-0.75	0.75-1	>1
Goldfields Esperance	3%	15%	34%	19%	11%	18%
Wheatbelt	3%	13%	29%	20%	12%	23%

- Developed model tends to predict rutting well with some variation
- It underpredicts rutting for older pavements where the observed rutting is substantially higher
- The above is due to the linear nature of the developed model.

Key Findings

- Average rut progression for WA ranges from 0.4-0.7 mm/year
- Kimberley has the highest rut progression rates, which may due to environmental impact and low design standard
- Metropolitan has the lowest rut progression rates, therefore asphalt removal & replacement can address the majority of rut defects
- Network level condition data can be used in developing rut progression model
- Potential benefits from the developed model are

✓ Overall lowering of total transport cost due to more targeted intervention

✓ Lowering of risk due to the above.

Directions for Future Work

Stage 4 (concept approved)

- Develop treatment selection decision matrix to investigate and determine the variables that can identify and initiate **Pavement Repair** and preservation treatment needs on the MRWA road network.
- Develop a methodology that helps practitioners to compare treatment alternatives in terms of risk, Level of Service, and Whole of Life Cost, when budgetary constraints are posed on their work programs.
- The scope will include micro surfacing, strip sealing (seal wheel paths only) and rip and seal treatments as corrector layers, enrichment/rejuvenation and pavement repair.
- These will extend the heavier rehabilitation treatments examined to date and have a significant role in Main Roads' continuous efforts to deliver cost effective programs.

Final Remarks

Acknowledgements

Tyrone Toole, Ammar Mohammed, Lalinda Karunaratne,
Natalie Lockwood & Desiree Hamann.

Success Factors
- ✓ Two entities, ONE team
- ✓ Long term planning

Future Direction
- ✓ Network level data
- ✓ New data sources
- ✓ Artificial Intelligence & Machine Learning.

Questions?

Thank You