

Rail Damage Functions Associated with Automatic Train Operation

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- Automatic Train Operation (ATO) on London Underground
- Capacity Challenges
- Rail Damage associated with ATO
 - Squat Type Defects
 - Corrugation



Worlds first ATO railway 1969



<https://www.ltmuseum.co.uk/collections/collections-online/photographs/item/2011-11258>

<https://www.ltmuseum.co.uk/collections/collections-online/photographs/item/2011-11258>



ATO on London Underground

- Victoria Line 1969 (upgraded 2011)
- Central Line (incl W&C) 2000
- Jubilee Line 2011
- Northern Line 2014
- District, Hammersmith & City, Circle, Metropolitan, 2019-
- Bakerloo & Piccadilly?



Inherent Infrastructure Challenges

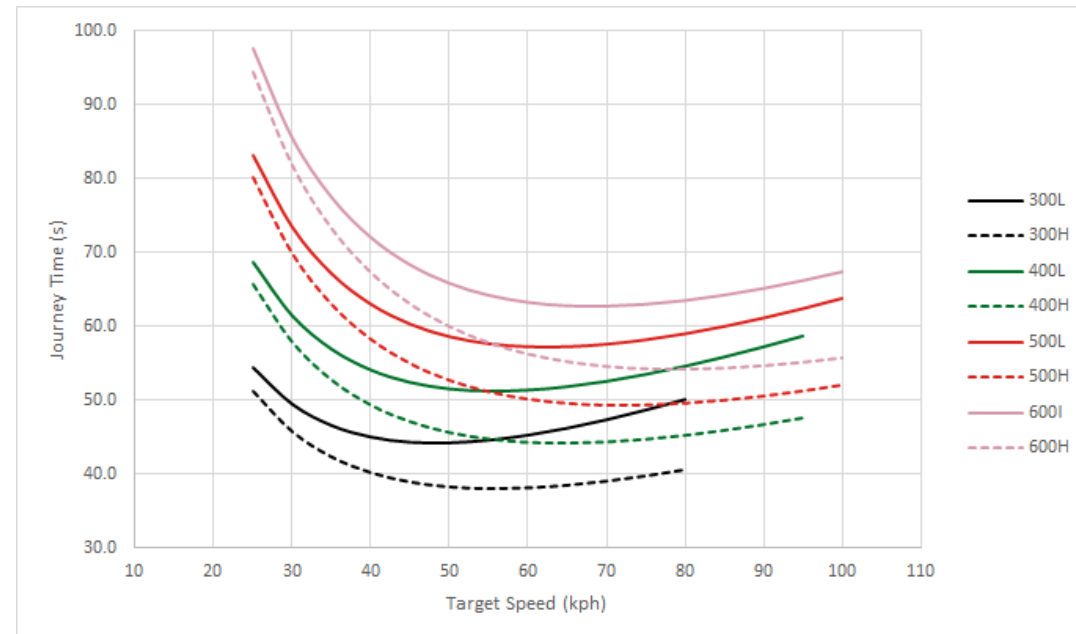
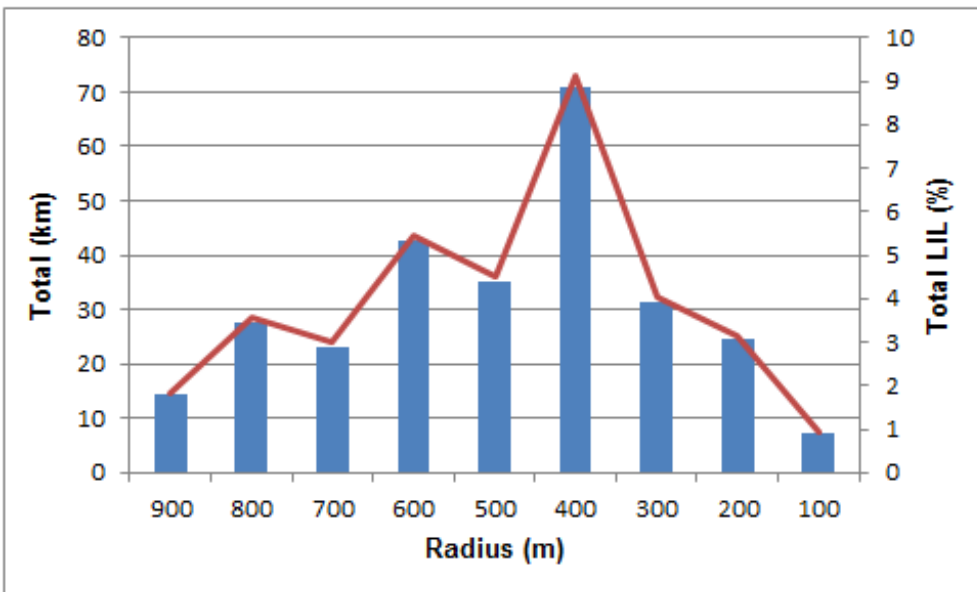


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Speed isn't everything....

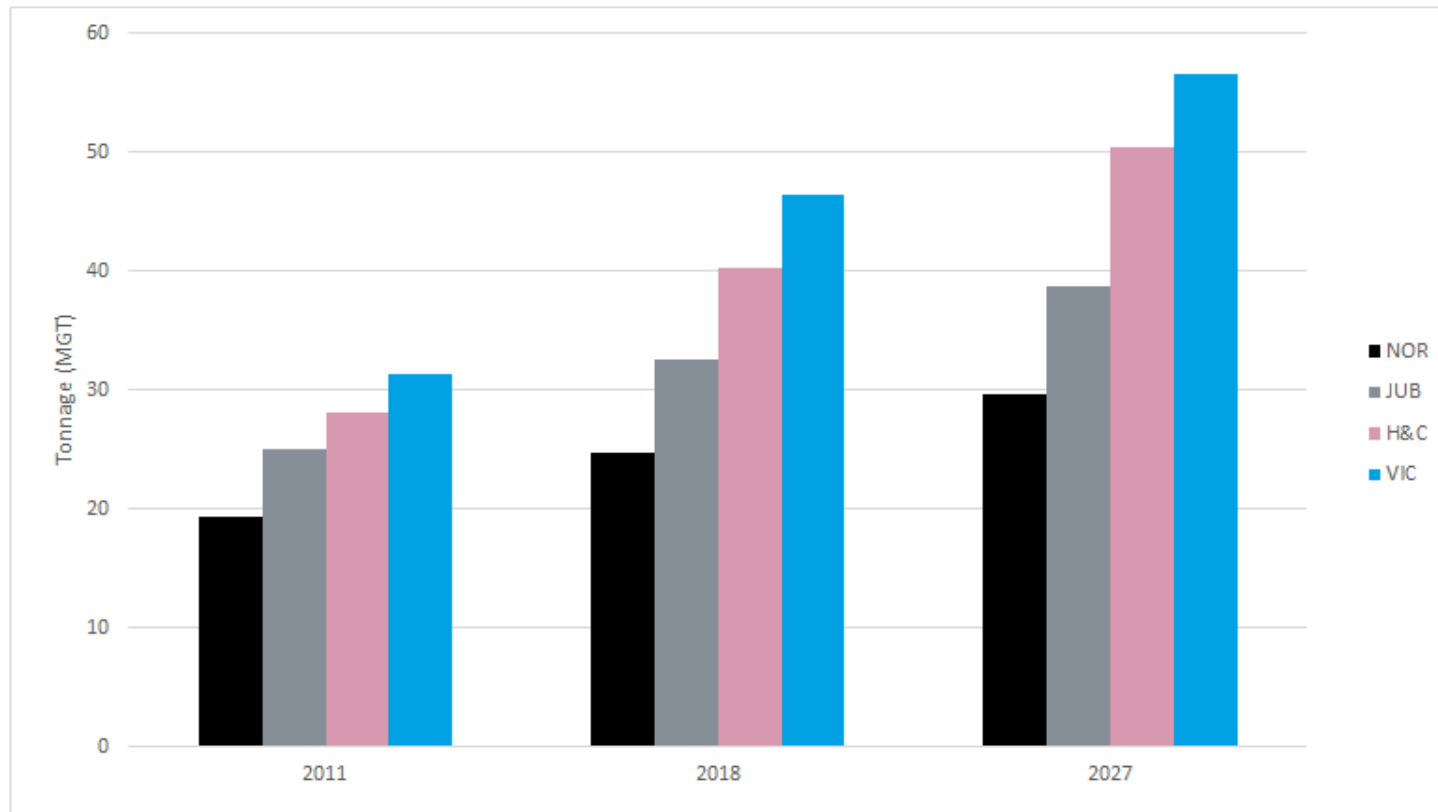


Capacity Conundrum

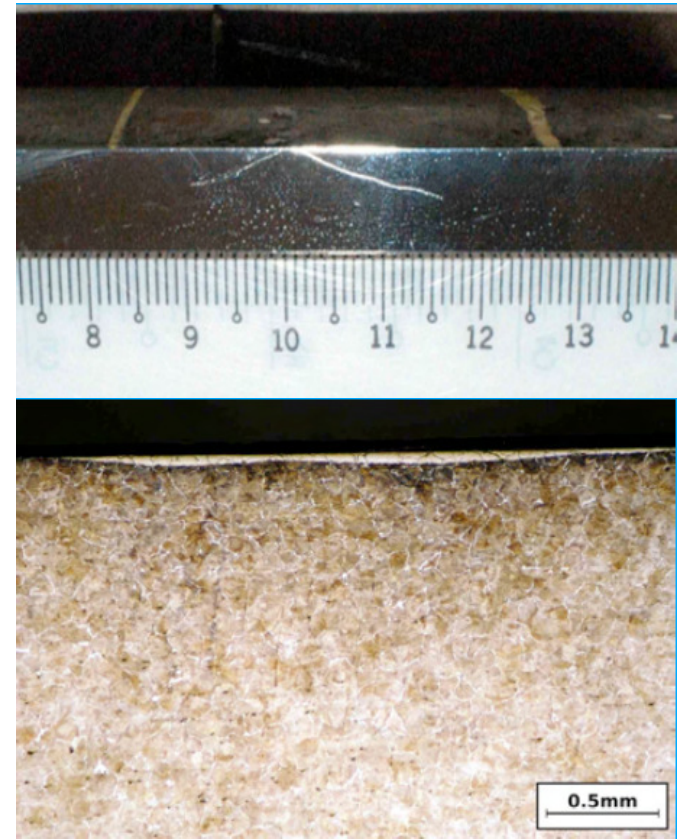
- How can't we increase capacity?
 - Bigger Trains: Need bigger tunnels
 - Longer Trains: Need new platforms in tunnels
 - Faster Trains: A bit faster....but inherent geometry limiting
- How can we increase capacity?
 - Run more trains, closer together
 - Inter station lengths short, acceleration and braking more important
 - More trains = Greater Tonnages



ATO = Tonnage Increase

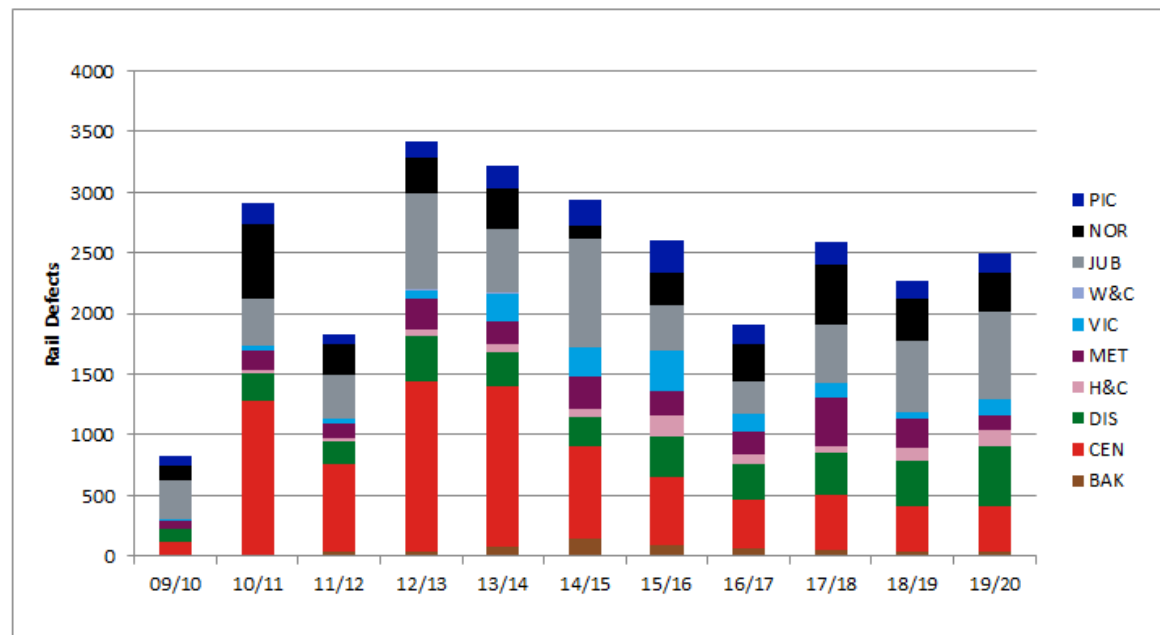


55% is Open



Squat Type Defects

- Open sections
- AC Traction Systems
- Concentrated in areas of congestion, rarely in platforms
- Martensitic layer present above cracks
- Explosion in numbers found post ATO commissioning



- Why?

1. Studs: A squat type defect in rails
Grassie, S.L., Fletcher, D.I., Gallardo Hernandez, E.A & Summers, P.
Proc. IMechE Vol 226F, p. 243 – 256,
Part F: J. Rail and Rapid Transit, 2012.

2. Simulation study of thermally initiated rail defects
Scott, D, Fletcher, D.I. & Cardwell B.J.
Proc. IMechE Vol 228(2)F, p. 113 – 127,
Part F: J. Rail and Rapid Transit, 2012.



Squat Type Defects

- Not the same as conventional squats¹
- Need low adhesion conditions on railhead, rarely found in tunnels²
- Low speed slip recovery in 'damp' conditions, not 'contaminated' adhesion conditions²
- Simulations show capable of producing $T\gamma$ in excess of 2200J/m, capable of producing temperatures greater than 727°C to produce martensite²
- Manual driving much better at coping with low adhesion, not necessarily at maintaining timetables hence ATO.
- Best option is to re-design Wheel Slip Protection (S-Stock), however not a quick fix.....



Standard Changes

Standard Category 1

S1178 A2 Rail Defect Management

Table 12: Minimum actions for a transverse defect (potentially from a squat, squat-type, wheelburn, shelling defect) in the head of the rail (code: 127, 129, 227, 211, 2291, 2292)

Defect description	Defect size	Position	Minimum Action
Transverse defect	≤50mm long, horizontal or down turning crack 1 to 10mm deep	Outside FPL	3M*
		Within FPL	3M*
Transverse defect	≤50mm long, horizontal or down turning crack >10 to 15mm deep	Outside FPL	2C
		Within FPL	3B
Transverse defect	≤50mm long, horizontal or down turning crack >15mm deep	Outside FPL	2B
		Within FPL	1A
Transverse defect	>50mm long, horizontal or down turning crack 1 to 10mm deep	Outside FPL	3C
		Within FPL	3C
Transverse defect	>50mm long, horizontal or down turning crack >10 to 15mm deep	Outside FPL	2C
		Within FPL	1A
Transverse defect	>50mm long, horizontal or down turning crack >15mm deep	Outside FPL	2A
		Within FPL	1A

* Where bolt holes cannot be assessed, the minimum action shall be upgraded to a 3G.

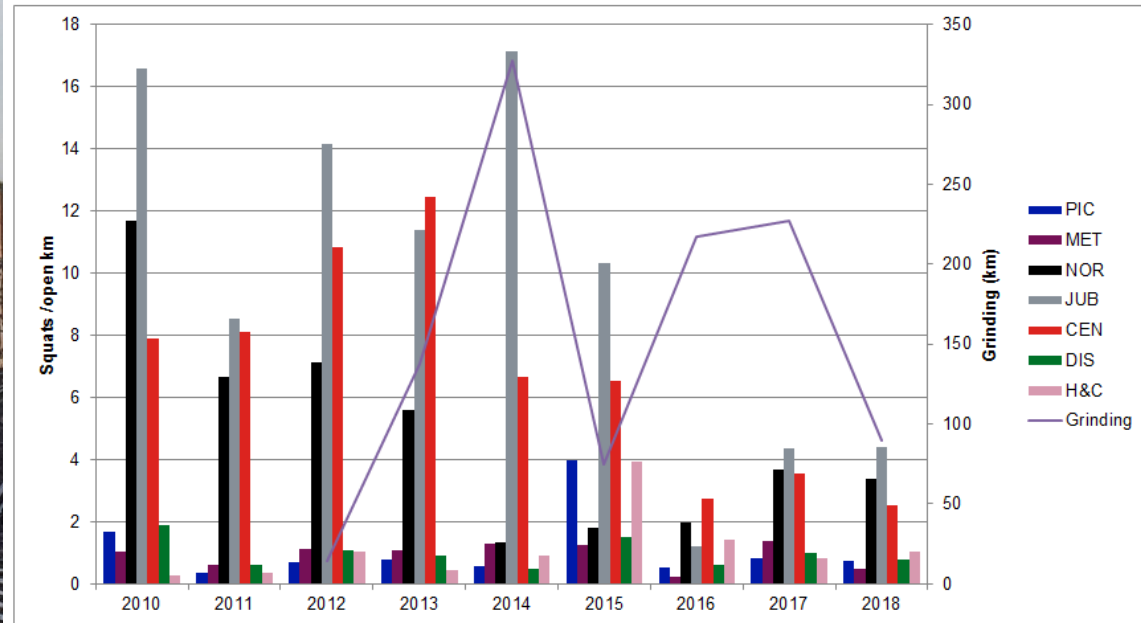
Table 1: Minimum Action Codes (MACs)

MAC	Minimum action to be taken
1	Impose 20mph Emergency Speed Restriction (ESR) (≤22mph for Automatic Train Operations (ATO) lines) and fit emergency clamped fishplates (Note 1. Refer to section 3.10 where it is not possible to fit clamps)
2	Fit emergency clamped fishplates
3	No emergency action required
5	Impose 10mph ESR (≤11mph for ATO lines) and fit emergency clamped fishplates (refer to clause 3.10 where it is not possible to fit clamps)
A	Remove defect within 48 hours
B	Remove defect within 7 days
C	Remove defect within 13 weeks (recommended within ultrasonic inspection interval)
G	Make testable and retest using any approved NDT method (note 2) within 7 days
M	Retest (URFD) / Monitor to specified frequency of UIIP
R	Refer to RSCM data results (note 3) within 7 days
U	Re-profile, grind, weld repair or remove 7 days prior to next URFD inspection
Y	Re-inspect (visual) twice weekly

- Rarely grow
- Ultrasonic Interval set by tonnage/defects
- Allows more time for them to be removed if required.....
- Multiple by re-railing or headwash welding process approved



Preventative Grinding



Thunderground!



Thunderground: noisy Northern line sparks most Tube complaints

Joe Talora

THE Northern line has been labelled the Tube's noisiest after being the subject of more complaints from people living nearby than any other in the past four years.

Transport for London received 282 residential noise and vibration complaints about the Northern line between 2018 and February 2022, new figures show. The Victoria line saw only slightly fewer noise and vibration complaints (252) in that time.

Third worst was the District line with 138 complaints, followed by the Jubilee line, on 108, despite it being one of the newest lines on the network.

Noise has been less of an issue on the Bakerloo and Metropolitan lines, with 17 and 28 complaints respectively.

The figures were revealed by Mayor Sadiq Khan following a written question from Lib Dem London Assembly Member Caroline Pidgeon about noise pollution on the Underground.

Mr Khan said TfL "understands the importance of minimising noise levels for neighbours, customers and staff" and revealed that 15,000 metres of rail-grinding work has been carried out in the past six months to smooth corrugated rails which are the "principal cause" of track noise.

An average of six complaints a month have been made about Northern line noise over the past four years, though

there were 58 complaints in July 2018. The following year, Tube drivers on the Northern line threatened industrial action over noise levels which were compared to those of a rock concert. Levels of up to 109.5 decibels were recorded, with the issue said to be worst on the High Barnet branch between Euston and Tufnell Park.

Drivers' union Aslef said in 2019 that a track fastening system known as Pandrol Vanguard was to blame for high levels of noise. Mr Khan revealed last week that TfL has "successfully trialled" the replacement of Pandrol Vanguard

282

Complaints about noise and vibration on the Northern line between 2018 and February

track fastenings on the Jubilee line, with initial results showing a reduction of in-carriage noise. He said: "TfL is now prioritising the replacement of Pandrol Vanguard in areas where in-carriage noise is a significant issue."

Residents of the Barbican, above the Circle, Hammersmith & City and Metropolitan lines, said in 2019 that noise levels of up to 53 decibels were recorded in some of their homes, exceeding World Health Organisation recommended limits.



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Corrugation



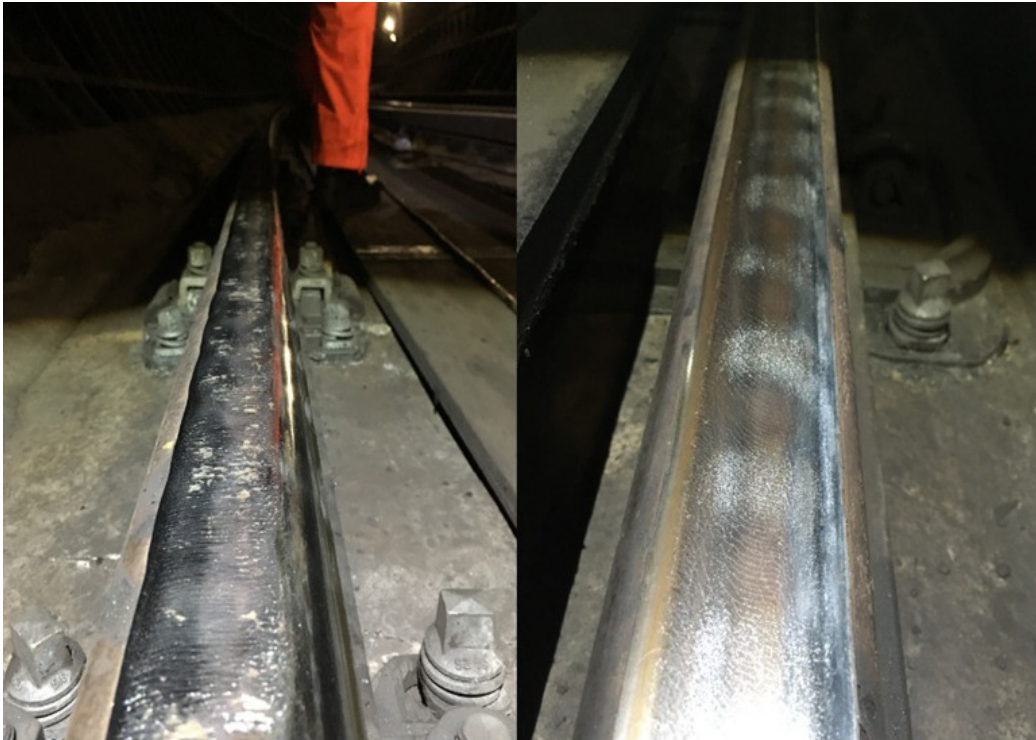
P2 Resonance



Pinned-Pinned



Corrugation



Rutting



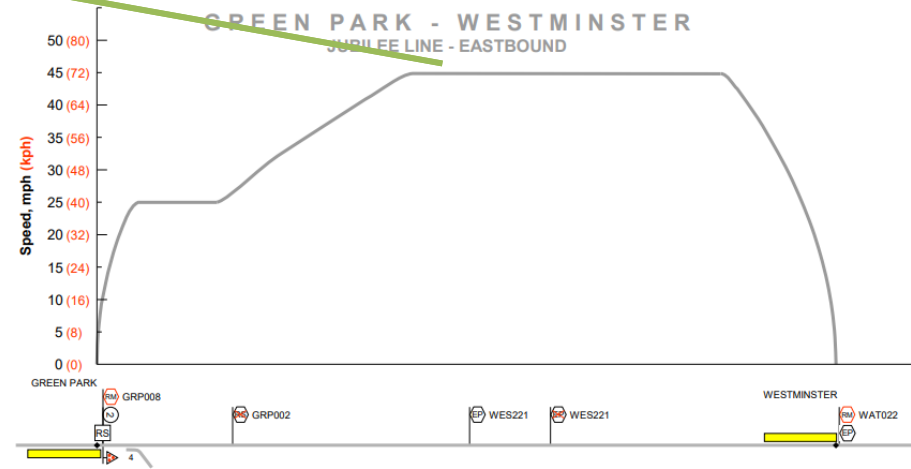
Trackform Specific



A Constant Frequency Phenomena ¹⁷



$$\lambda = \frac{v}{f}$$
$$f = \frac{v}{\lambda}$$



A Constant Frequency Phenomena ¹⁸

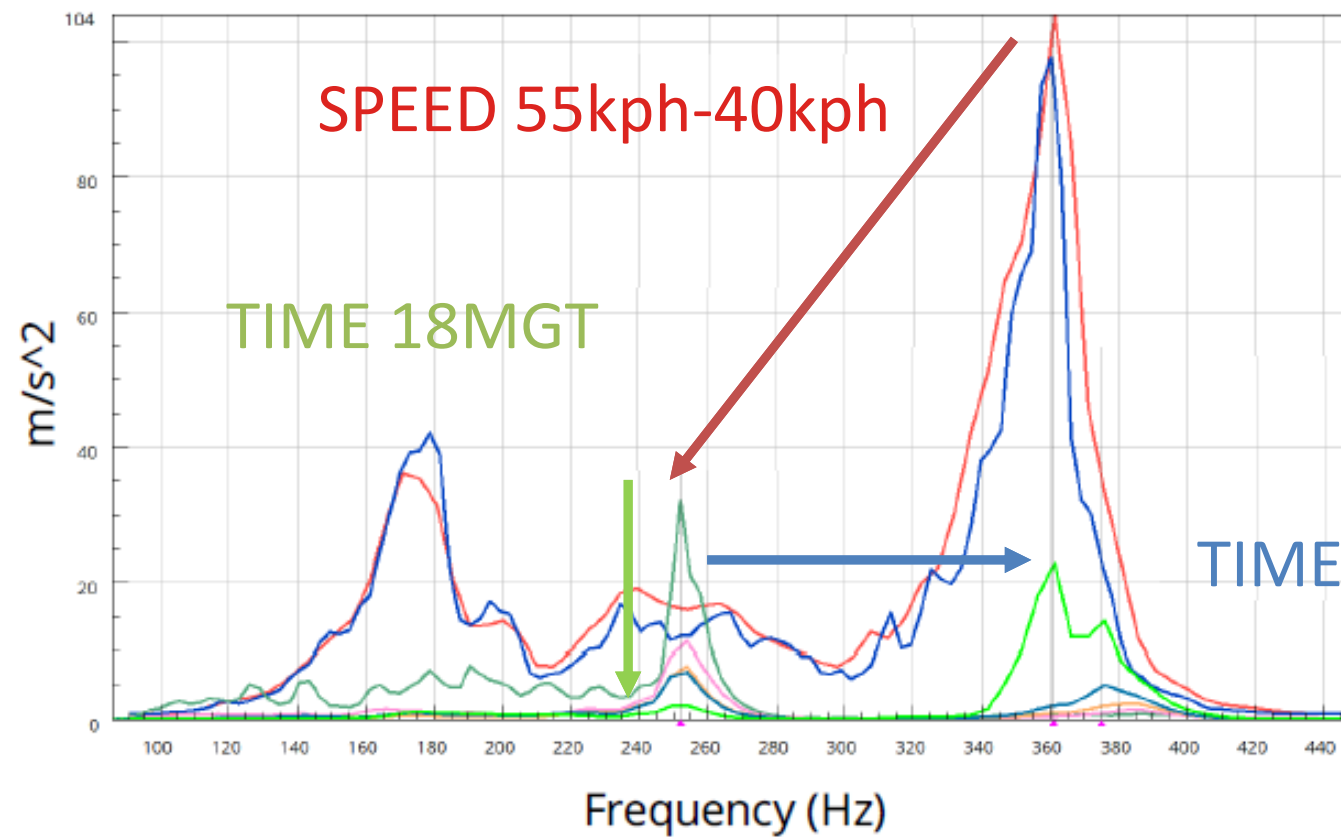


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Wearing out λ with Δv

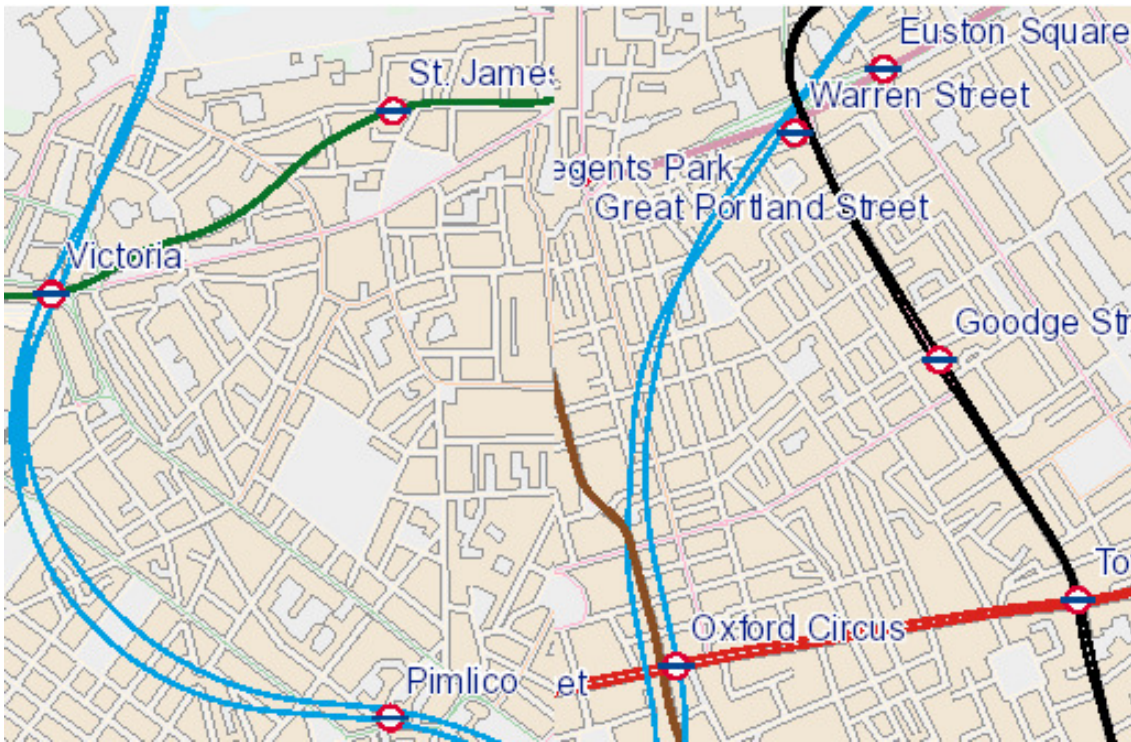


Marker	Title
—	2020-02-05_1hr_All_in1 Ch
—	2020-05-14_1hr_Full Speed
—	2020-05-14_1hr_40 kph_All
—	2020-09-02_40KPH_1hr_All
—	2020-11-10_40KPH_1hr_All
—	2021-01-05_40kph_1hr_All
—	2021-06-03_40kph_1hr_All

55kph@42mm = 360Hz
 40kph@42mm= 265Hz
 360Hz@40kph= 31.5mm



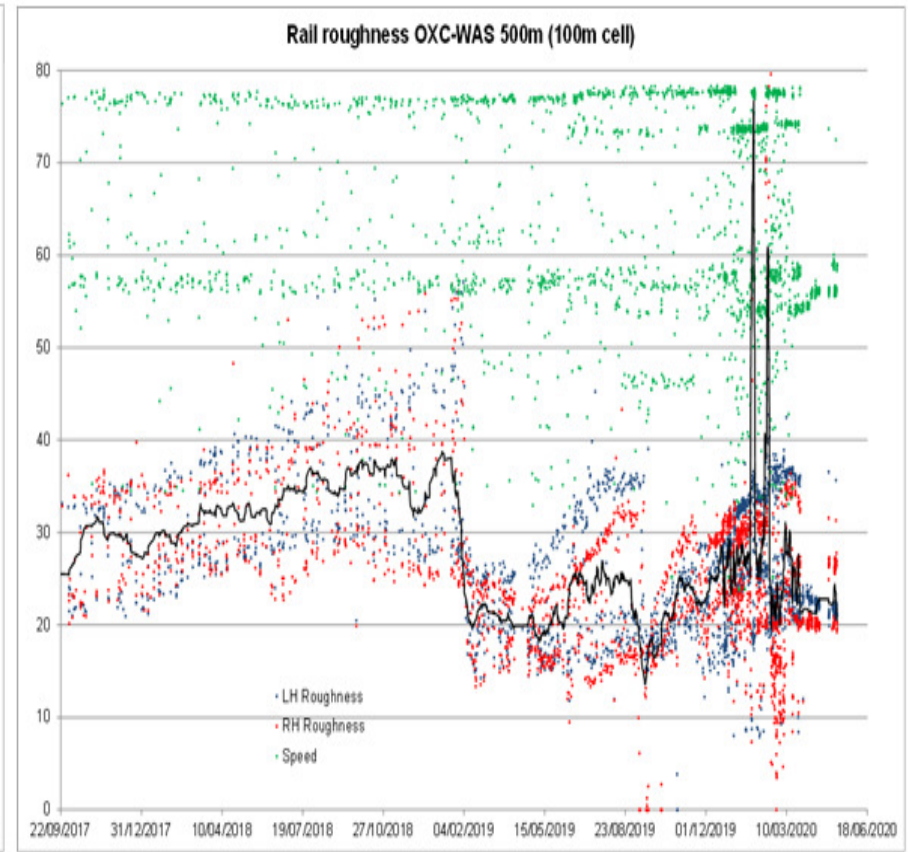
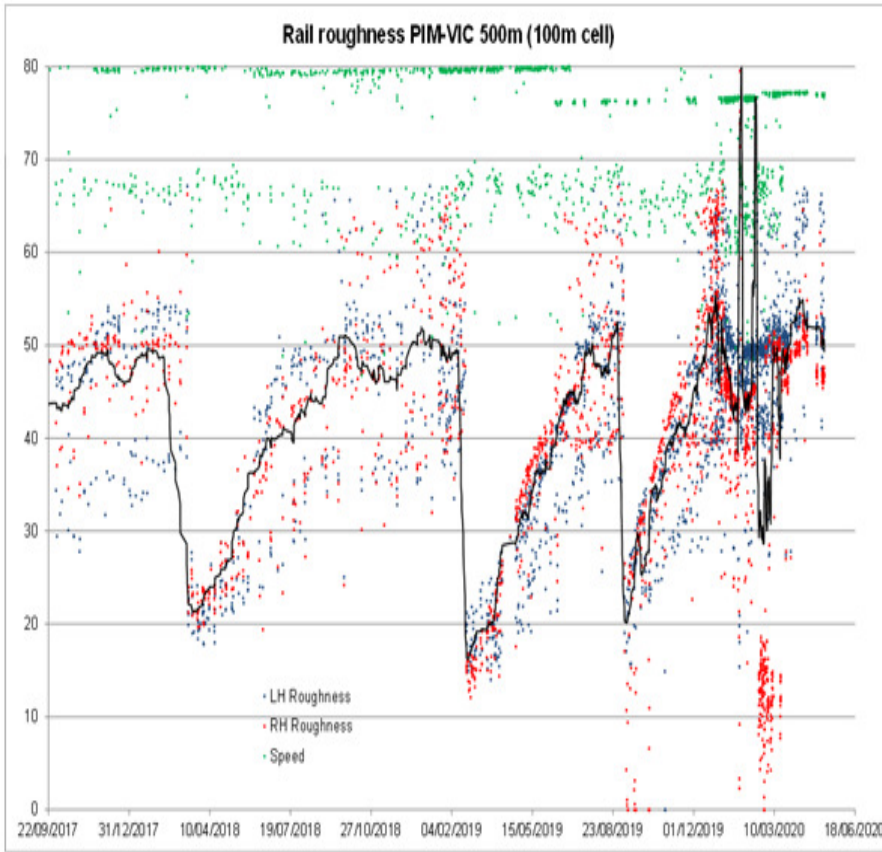
Speed Distribution



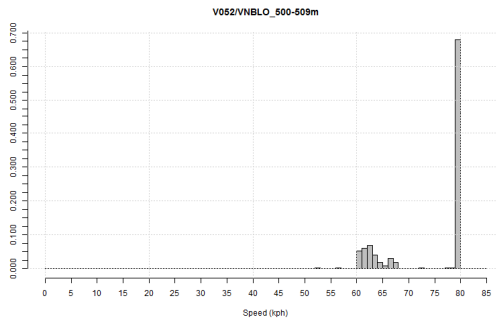
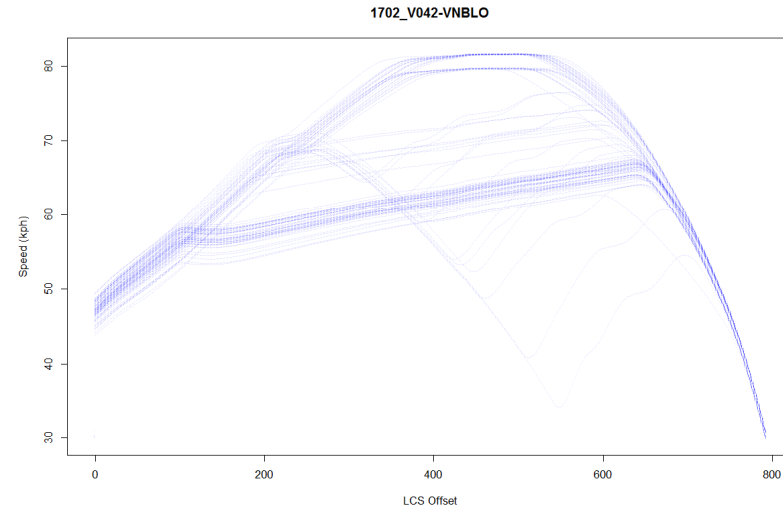
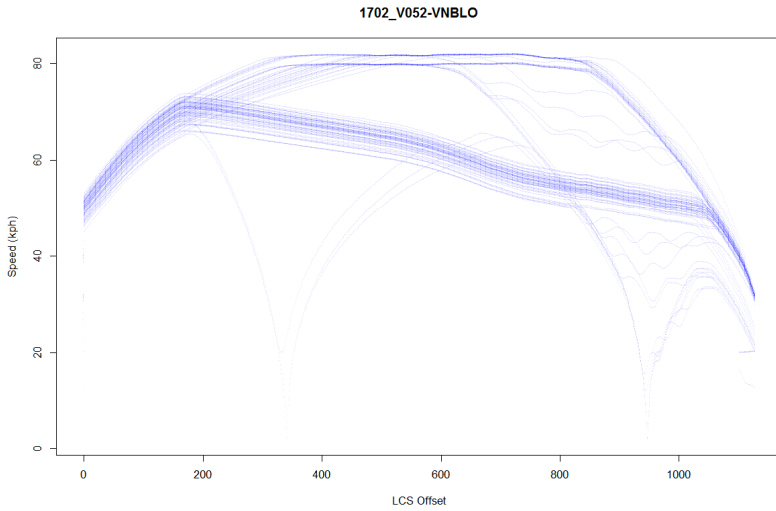
- Max Speed 80kph
- Curvatures c. 500m
- Tonnage Constant
- NTF15 with retrofit Pandrol Vanguard
- 50mm @ 80kph = 444Hz
- Pinned-pinned spacing c. 1m



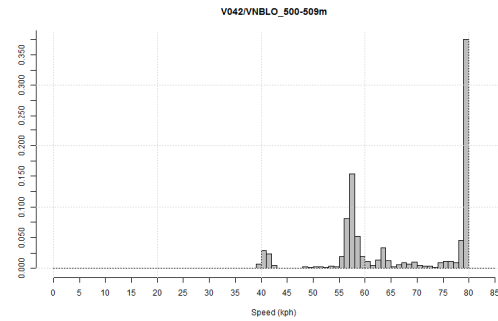
Roughness Growth



Roughness Growth



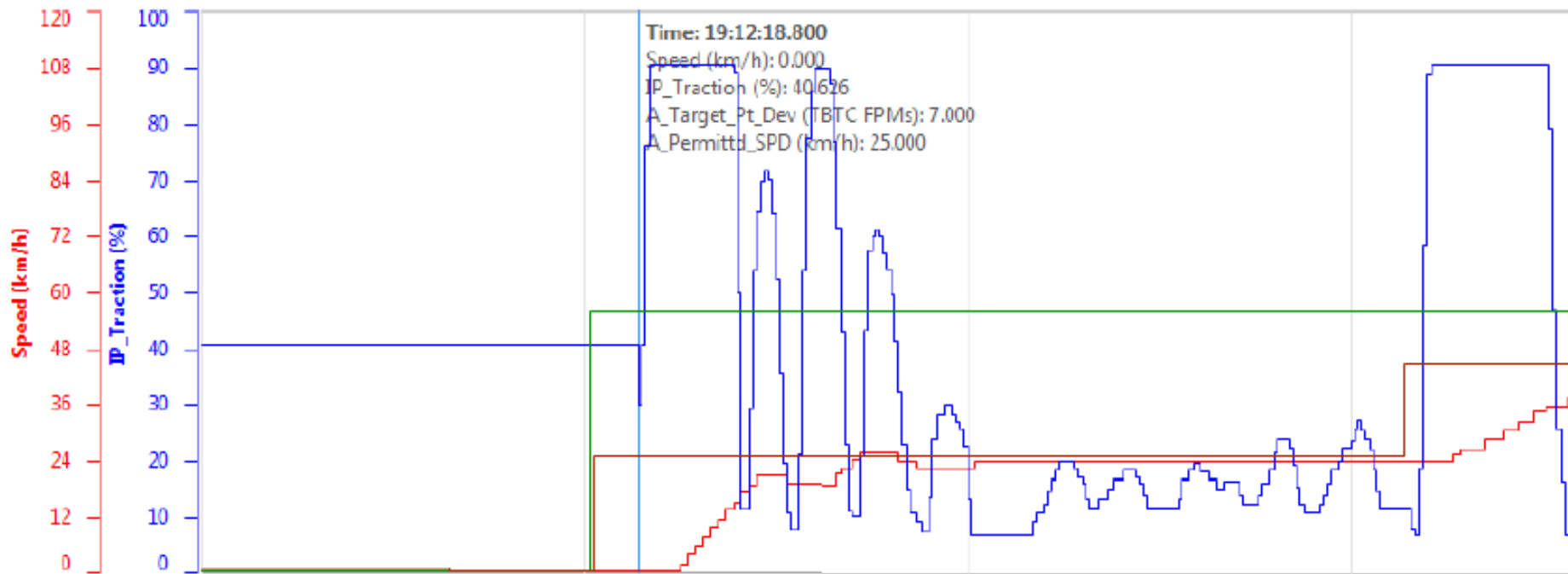
70% reach 80kph



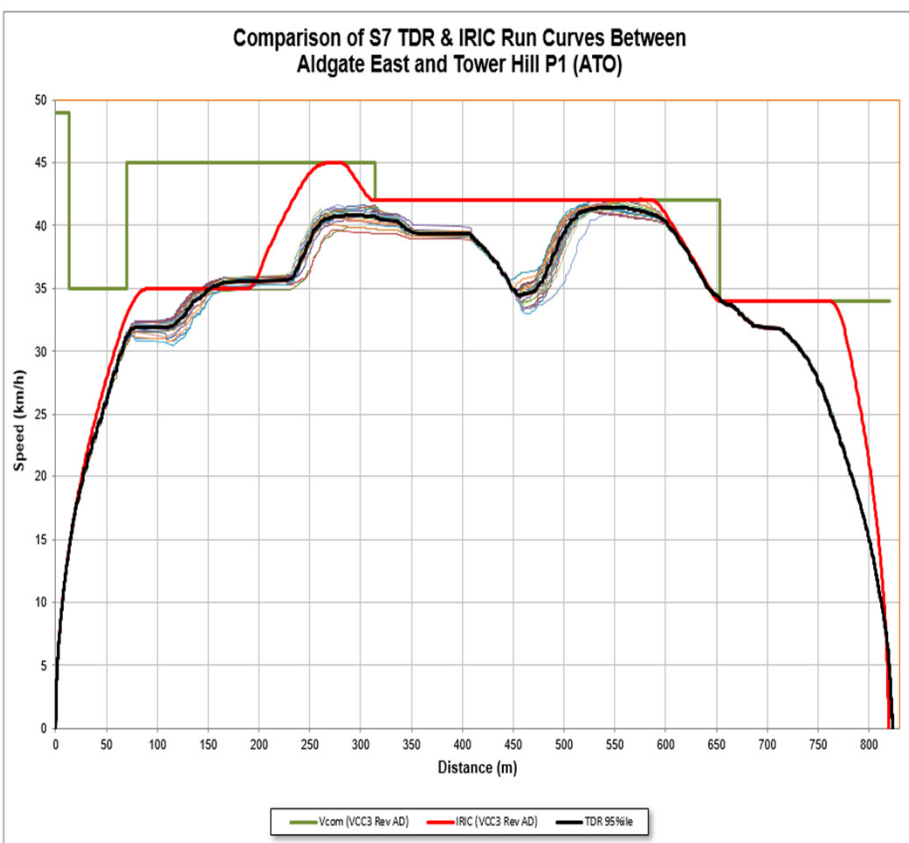
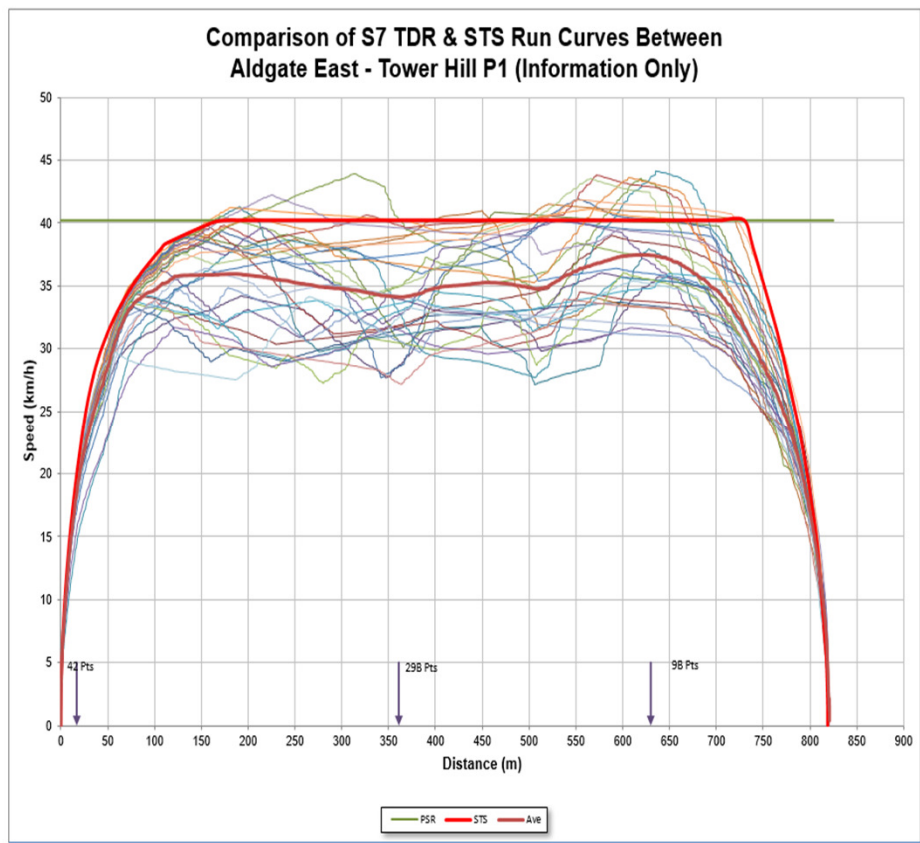
35% reach 80kph



ATO = No Coasting



Traction Destroys Curving

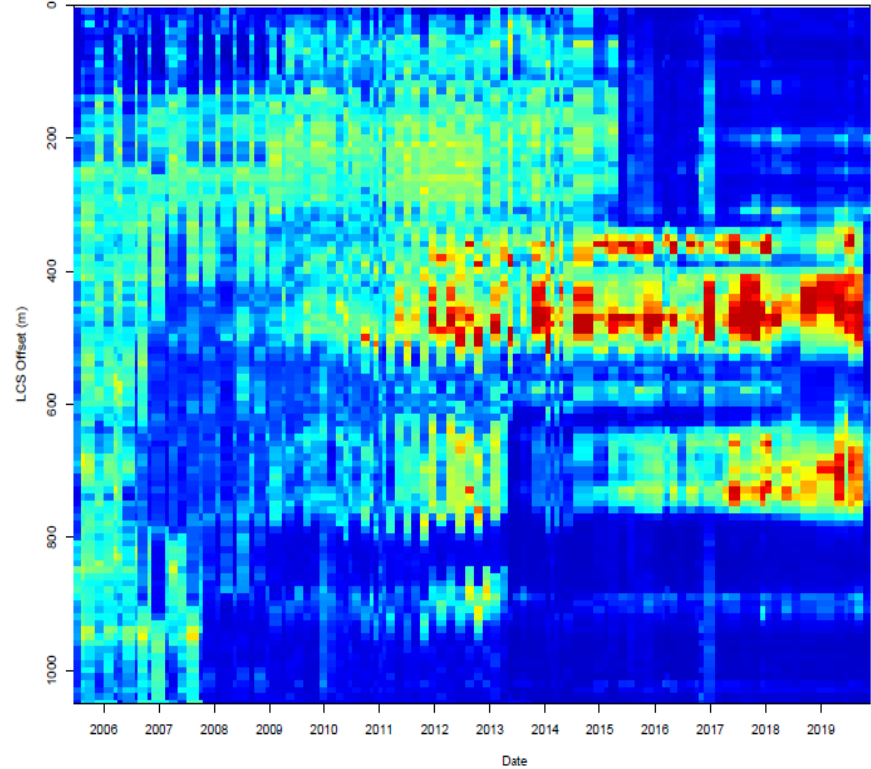
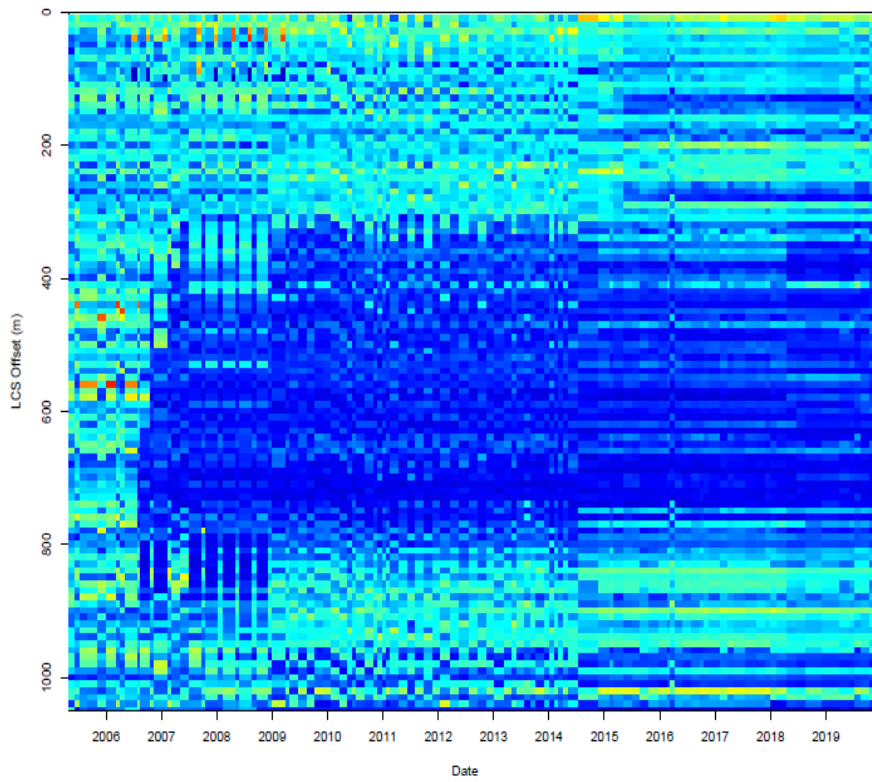


Not just rails that suffer...



Long Term Trends

N086/NNBFA - PLT3 CAMDEN TOWN TO PLT1 KENTISH TOWN



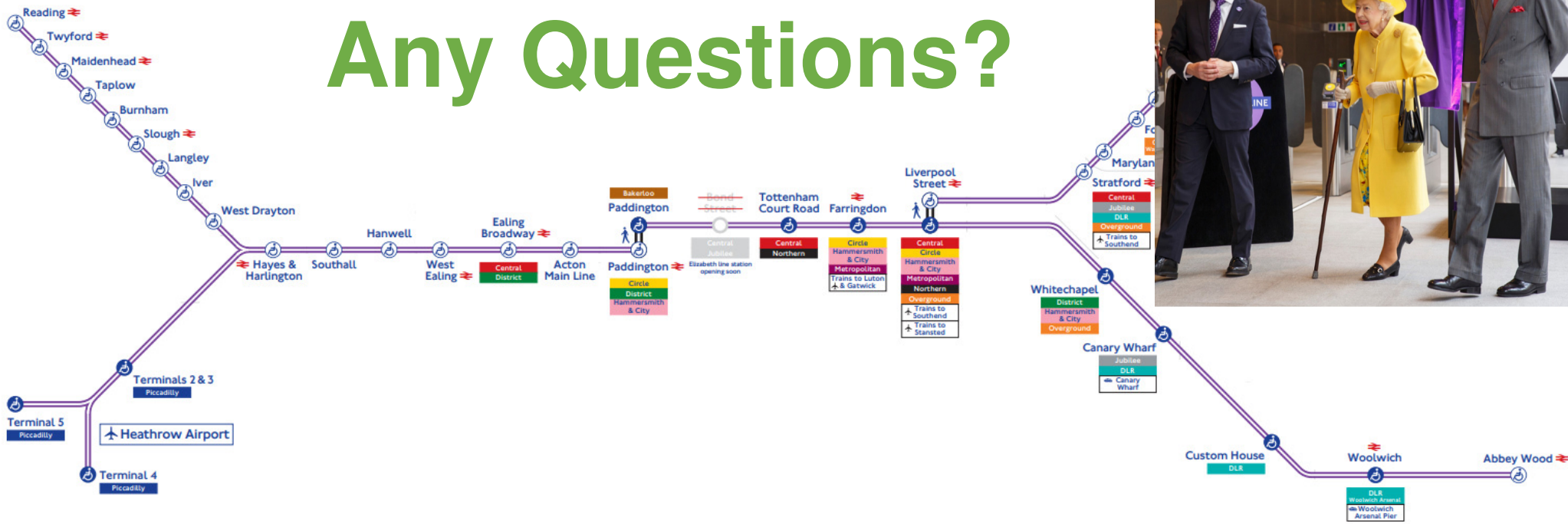
Conclusions

- ATO = Tonnage increases → Fatigue Cycles Reduced
- ATO = Poor low adhesion → Squat Type Defects
- ATO = Consistent Speeds → Corrugation Growth Rates
- ATO = Traction/Braking → Traction Destroys Curving



A brand new ATO railway.....

Thank You Any Questions?



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