# Investigation by VLI of Lateral Running Position of Wheelsets and the Symptomatic Damages to Wheelsets and Truck Components

**P. Bladon and D. D'Aoust**
**Wayside Inspection Devices, Rigaud, Québec, Canada**

**G. Castro and J. Santos**
**VLI S.A., Divinópolis, Minas Gerais, Brazil**

**Speaker: Paul Bladon**

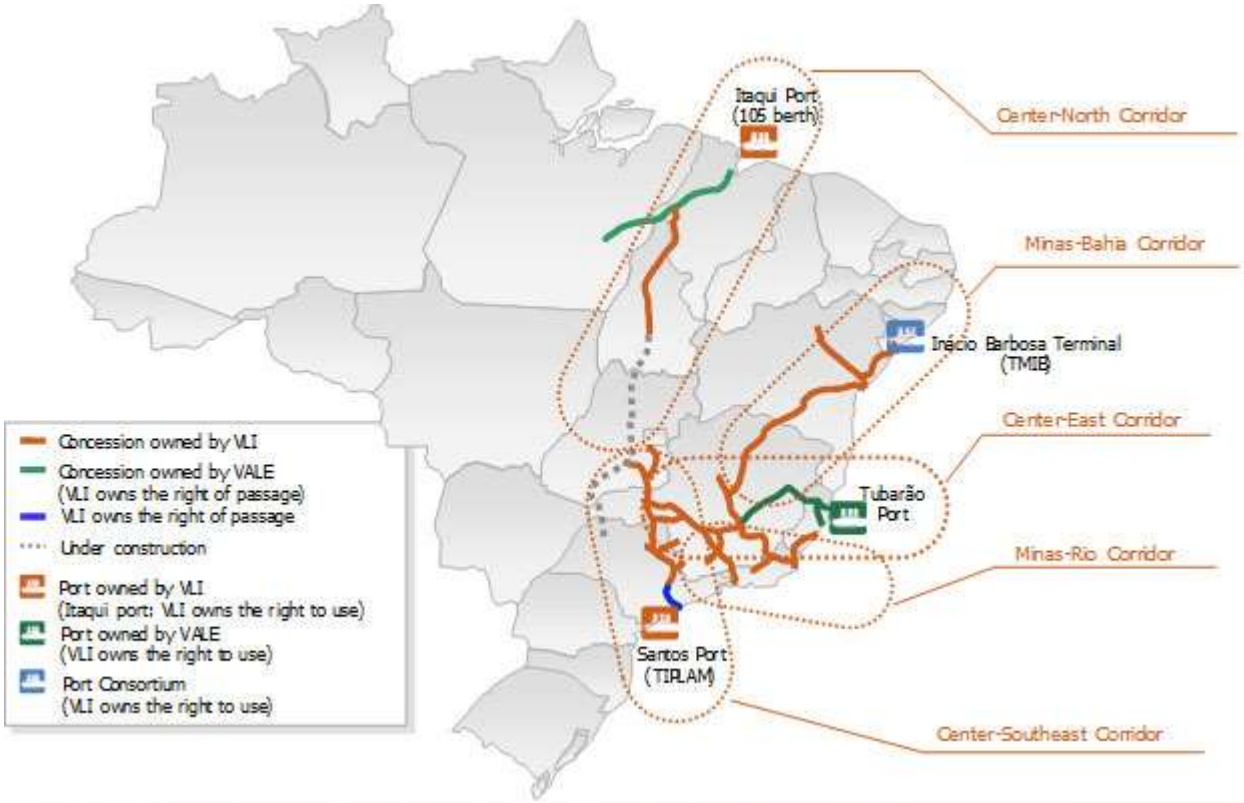
HEAVY HAUL SEMINAR • OCTOBER 20 - 21, 2021

WRI 2021

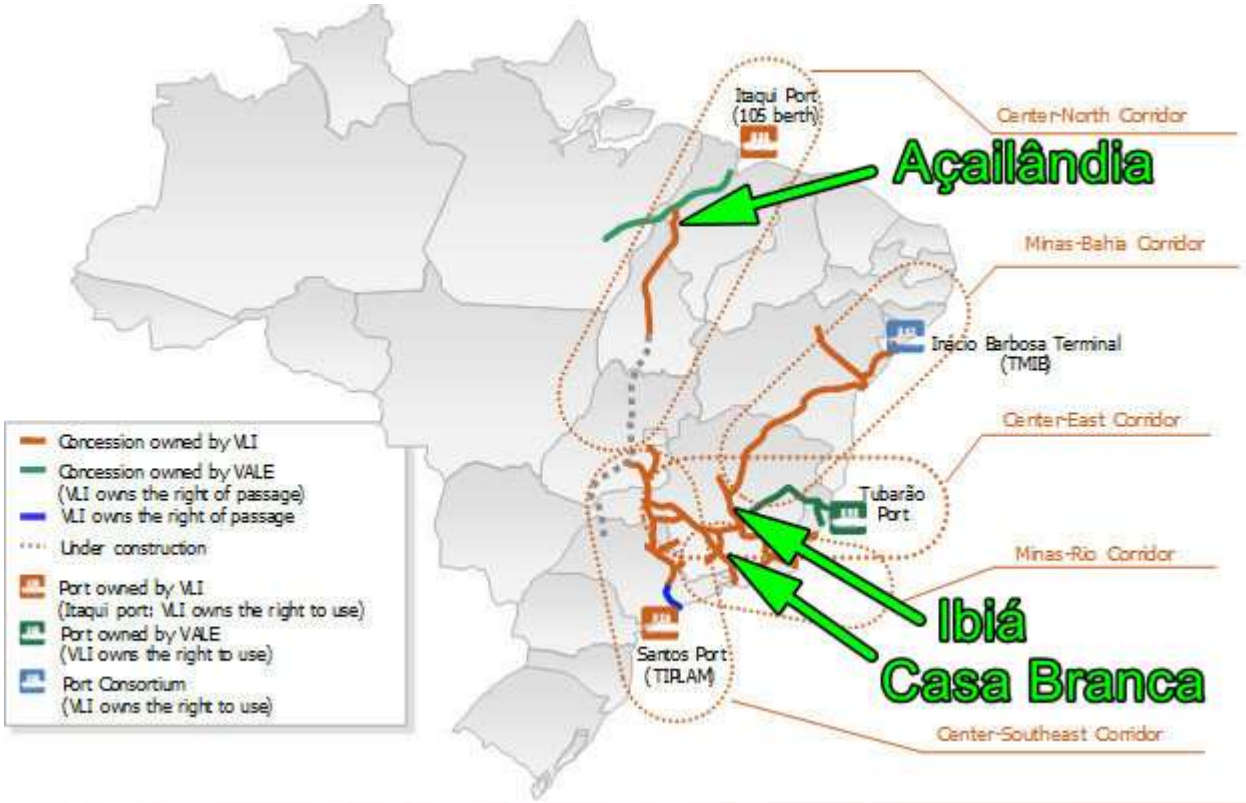
# VLI

- VLI S.A. (VLI) manages approximately 8,000 km of railway network in Brazil, and operate intermodal rolling stock.
- VLI undertook a study of bogie geometry metrics – principally the lateral position of wheelsets at line speed – and symptomatic damages shown on the wheelsets and bogie components.
- This study illustrated the inter-relationship between defective bogie geometry and the physical condition of components.

# VLI


Itaqui Port
(105 berth)
Center-North Corridor
Minas-Bahia Corridor
Inácio Barbosa Terminal
(TMIB)
Center-East Corridor
Tubarão
Port
Minas-Rio Corridor
Santos Port
(TIPLAM)
Center-Southeast Corridor
Concession owned by VLI
Concession owned by VALE
(VLI owns the right of passage)
VLI owns the right of passage
Under construction
Port owned by VLI
(Itaqui port: VLI owns the right to use)
Port owned by VALE
(VLI owns the right to use)
Port Consortium
(VLI owns the right to use)

# VLI


Itaqui Port
(105 berth)
Center-North Corridor
Açailândia
Minas-Bahia Corridor
Inácio Barbosa Terminal
(TMIB)
Center-East Corridor
Tubarão
Port
Minas-Rio Corridor
Ibiá
Casa Branca
Santos Port
(TIPLAM)
Center-Southeast Corridor
Concession owned by VLI
Concession owned by VALE
(VLI owns the right of passage)
VLI owns the right of passage
Under construction
Port owned by VLI
(Itaqui port: VLI owns the right to use)
Port owned by VALE
(VLI owns the right to use)
Port Consortium
(VLI owns the right to use)

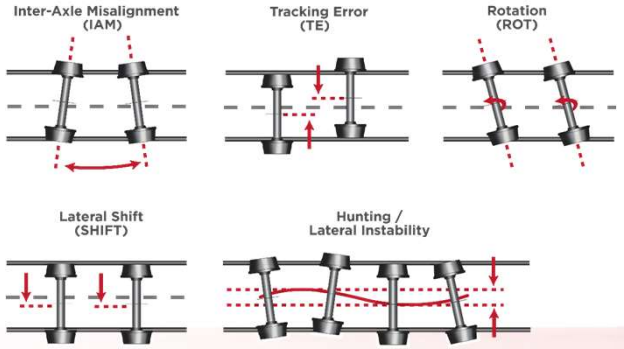
## The Study

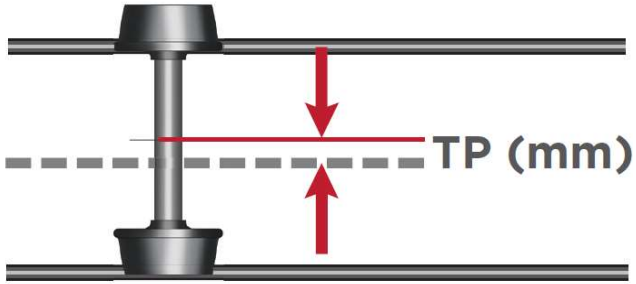
- **The study primarily used data collected by the TBOGI wayside system, but also used data from other sources where possible.**
- **The study also looked at how VLI are adapting their maintenance practices to address these issues.**
- **This is a proactive initiative by VLI to increase maintenance efficiency and increase the lifespan of rolling stock assets, with a focus on decreasing the wheel wear rate as this is currently the biggest problem for VLI on metric gauge.**

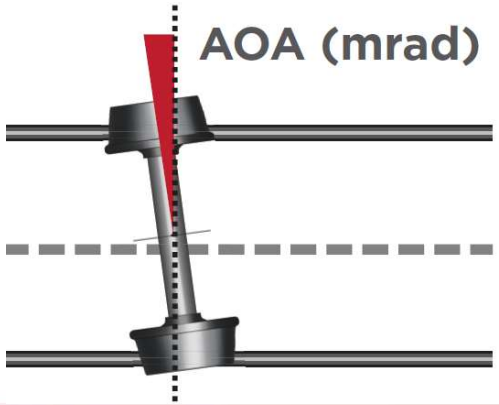
# WID

WAYSIDE
INSPECTION
DEVICES

# TBOGI

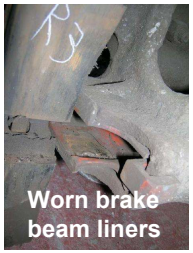

Inter-Axle Misalignment (IAM)
Tracking Error (TE)
Rotation (ROT)
Lateral Shift (SHIFT)
Hunting / Lateral Instability


TP (mm)

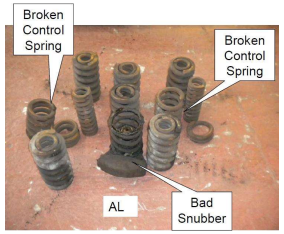

AOA (mrad)

# Tracking Position ∝ Wear & RCF

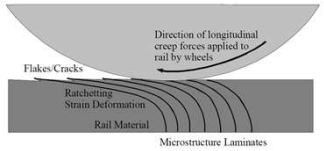
## Rolling Stock



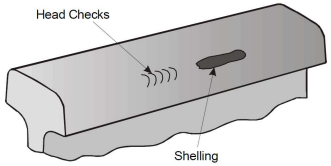


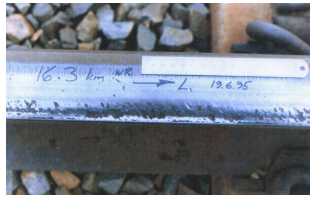


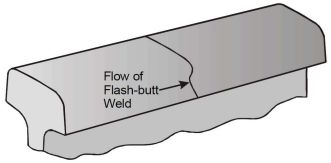

## Rail Infrastructure









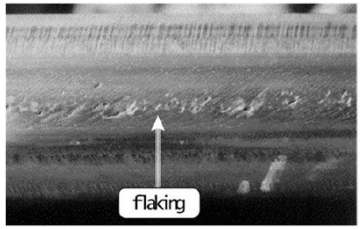


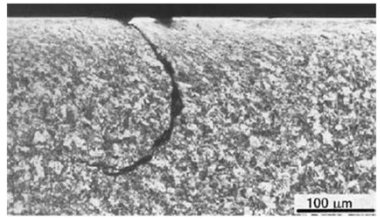
# Angle-of-Attack ∝ Wear & RCF

## Rolling Stock

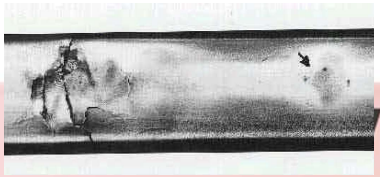



## Rail Infrastructure

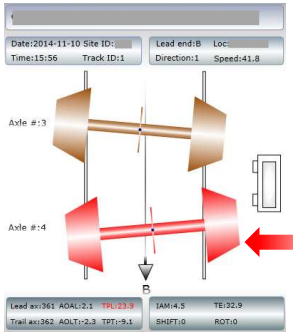


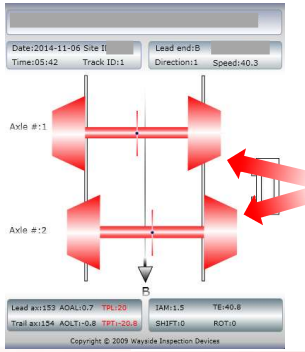




# Turnouts



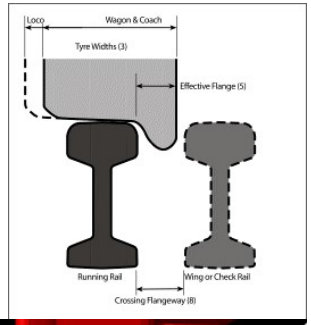

This wheelset 23.9 mm TP

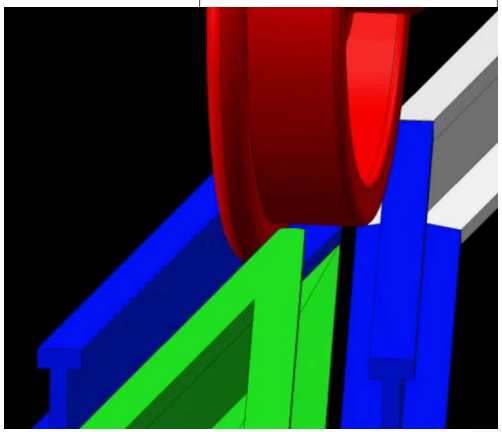



Both > ± 20 mm TP

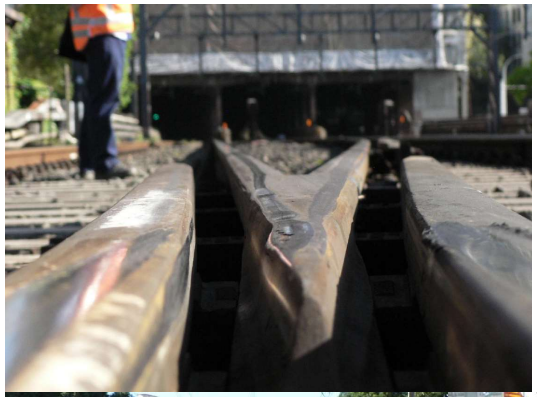
Flangeway = 45 mm
Typical flange = ~30 mm

> ± 15 mm can make contact



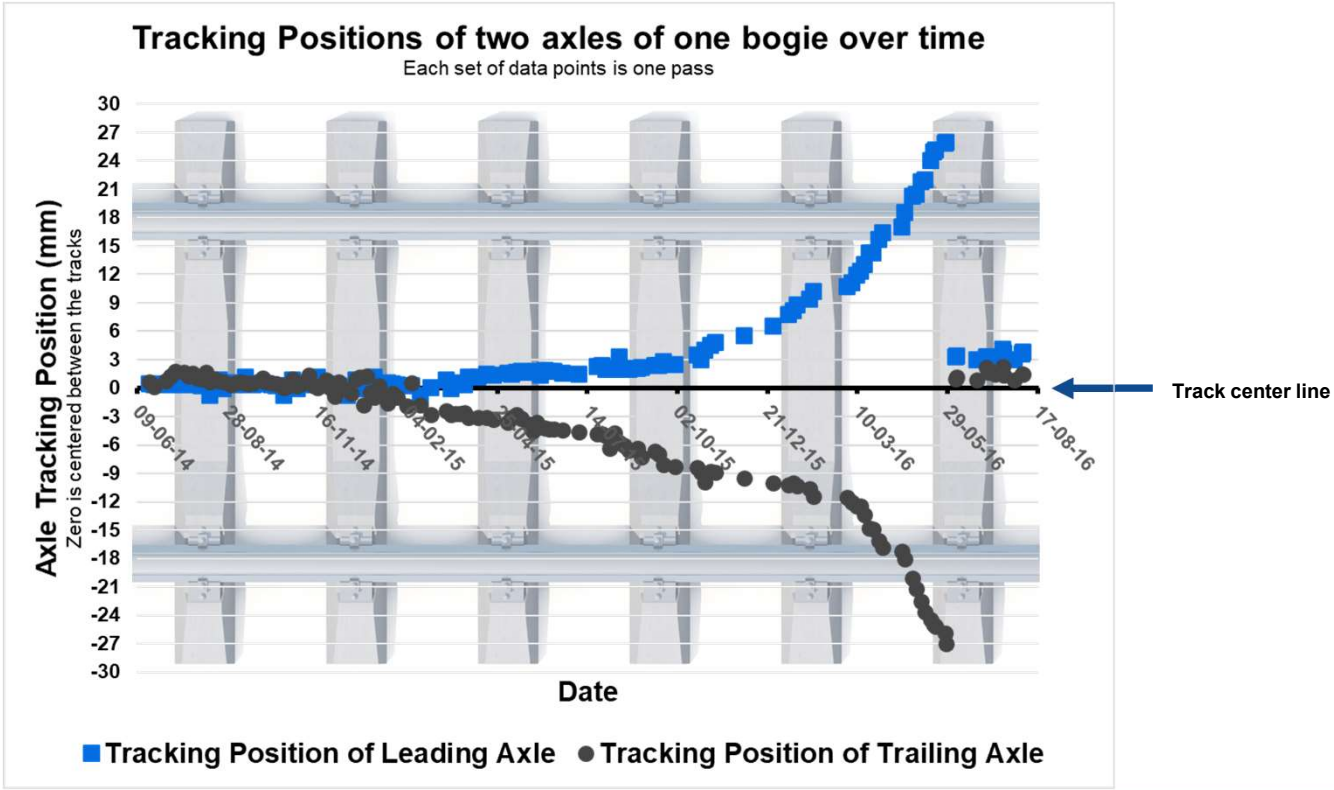



# Turnouts

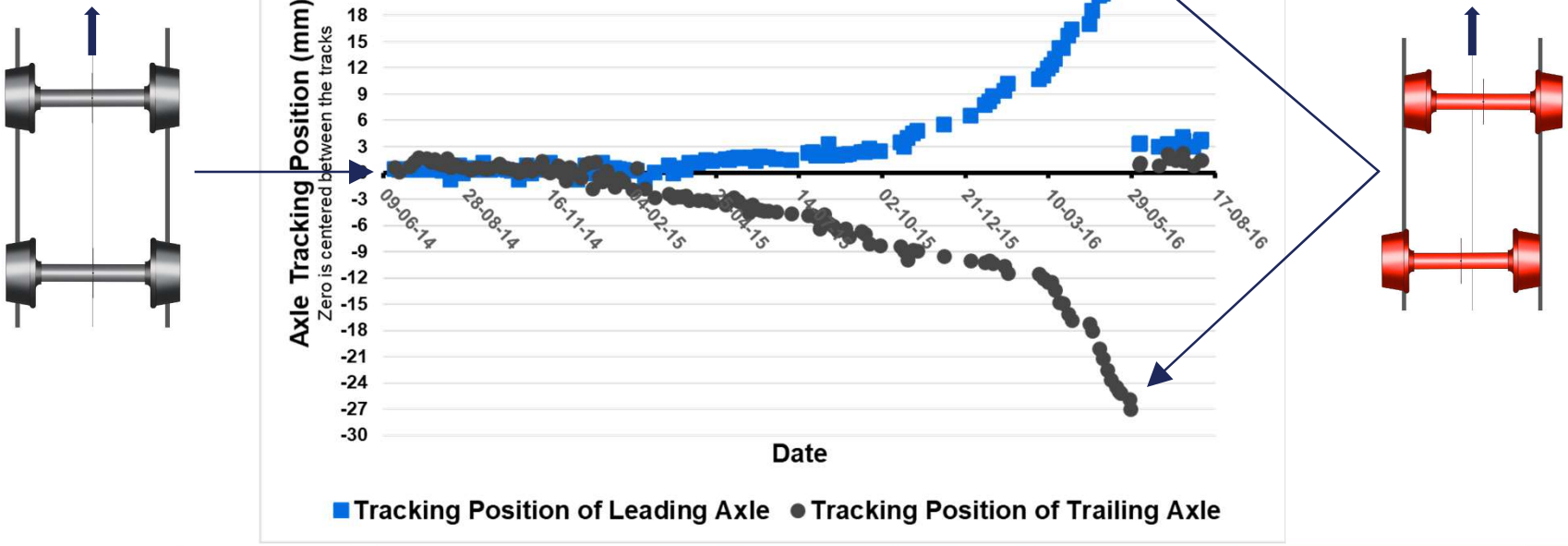



**Most common defects in turnouts are accumulated plastic deformation (lipping) and rail head checking.**

# Tracking Position (TP)



# Tracking Position (TP)



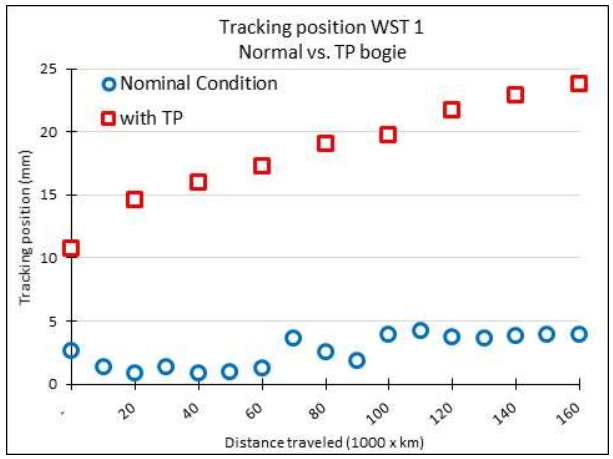
## Tracking Position (TP) and Wheel Wear

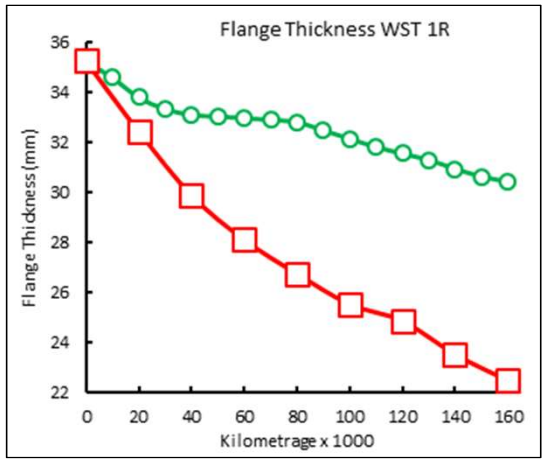
- **The magnitude and growth rate of the TP defect points to the component(s) that are defective.**
- **If left unchecked, the asymmetric wear pattern of the wheels triggers a self-feeding wear mode. This causes wear on other bogie components and prematurely wears wheels.**
- **The wear index for a bogie with a TP defect has been shown to incur an average 27% greater stress in the wheel-rail system.**

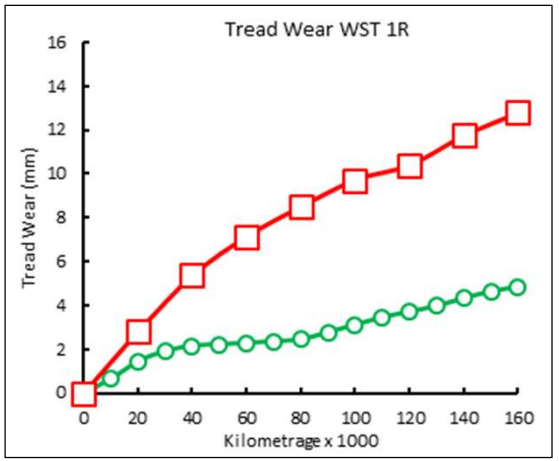
## Simulations

- **Simulations were created to test the effect of TP for VLI's specific combination of rolling stock and track network.**
- **Many factors were built into the simulation model to make it as representative of the VLI operating conditions as possible.**
- **Simulations were performed over 160,000 km distance traveled**

# Simulations



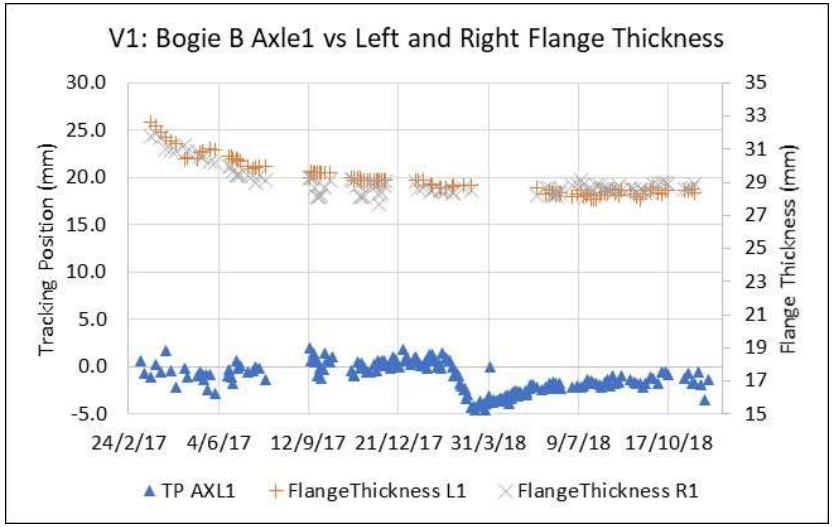



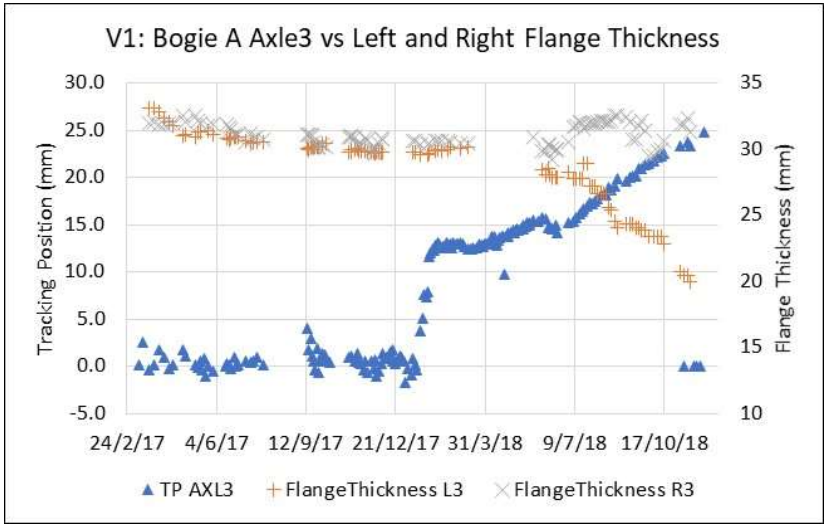

**A 5 mm rolling radius difference in the leading wheelset ($wst_1$) of the wagon was used to simulate the genesis of a TP defect**

# Real-World Data

**Two bogies of a vehicle**

**127,000 km over 20 months**

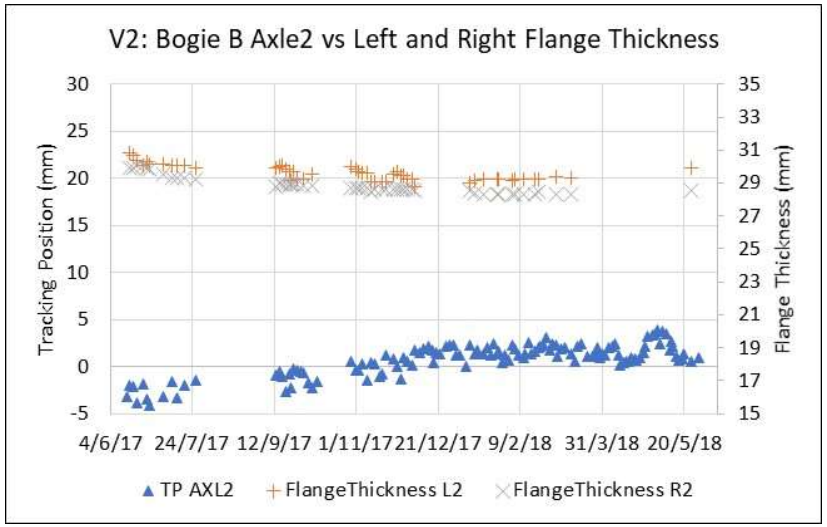


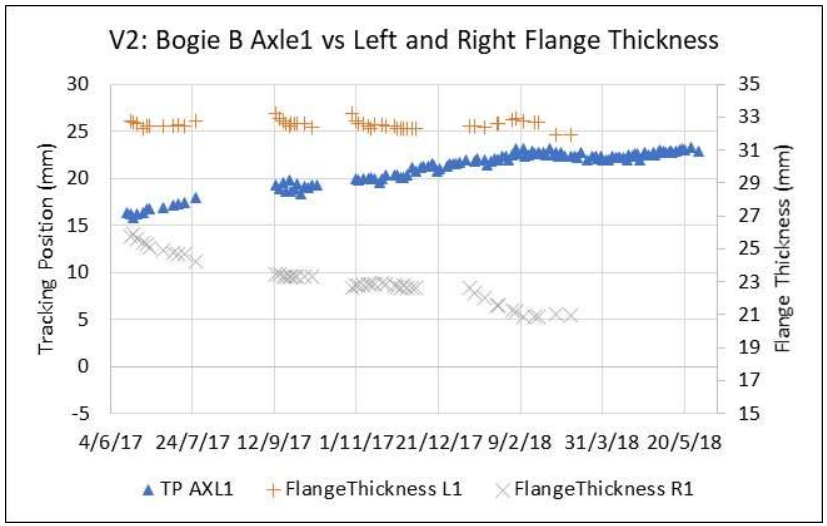



# Real-World Data

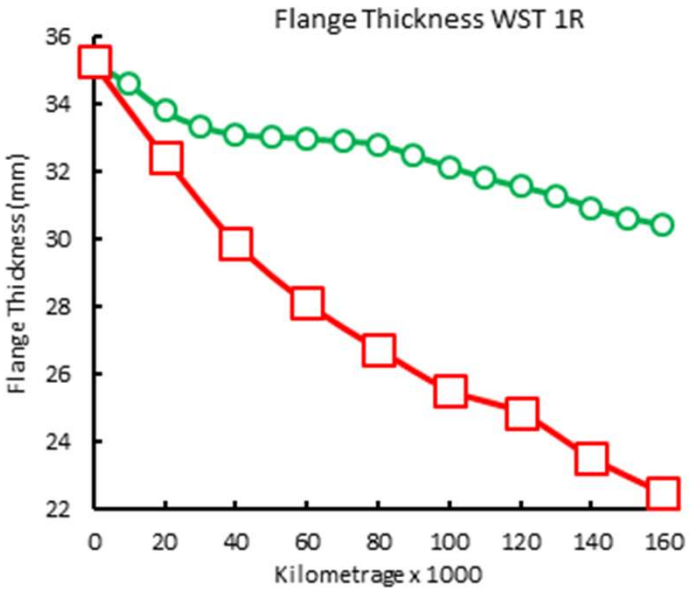
**Two axles of one bogie.**

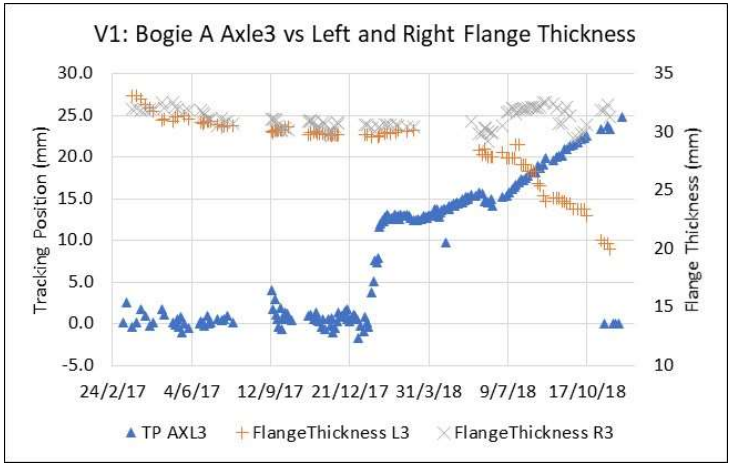
**86,000 km over 12 months**



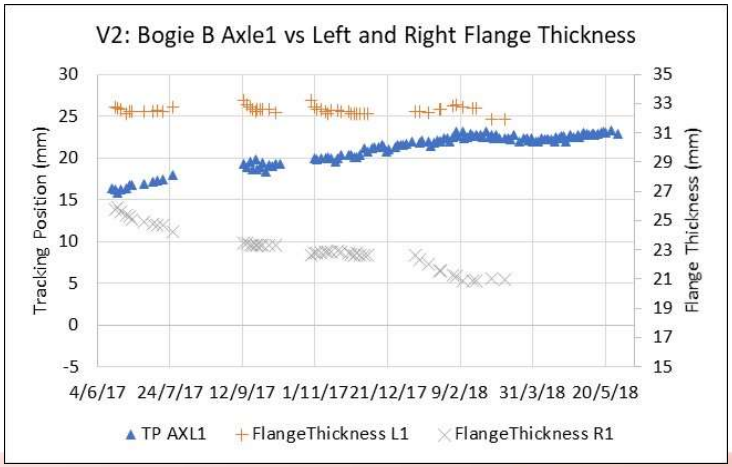



# Real-World Data




127,000 km




86,000 km

# VLI Maintenance Adaptations

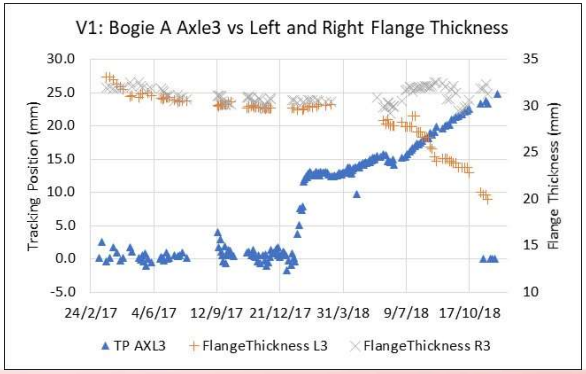
**Short Term:** Intervention of freight bogies with component(s) in critical state

**Medium Term:** Ranking of wagons for maintenance prioritization

**Long Term:** New strategy for maintenance planning based on freight car conditions

# VLI Maintenance Adaptations – Short Term

- **Corresponds most closely to the traditional go/no-go processing of wayside monitoring systems**
- **Any car that records a TP reading >|25| mm, or an AOA reading >|7| mrad is flagged in VLI's UNILOG system and a maintenance note is opened in SAP**
- **This strategy has been in operation at VLI since October 2018**



# VLI Maintenance Adaptations – Medium Term

1. **<u>Change of schedule:</u> Move from a manual inspection of 70 items on every car during every loading, to seasonal inspections staggered through the year. More time to inspect each asset, generating more information about the wagons.**

# VLI Maintenance Adaptations – Medium Term

2. <u>Creating a prioritisation ranking:</u> **Using data from multiple wayside systems and inspections to create a prioritized list of assets:**
   - **Hierarchical Analysis Process (AHP) was used.**
   - **The AHP is a weighted comparison of all wagons in each subgroup, running successive comparisons of asset condition data to assess the relative importance of each and assigning an inspection urgency score from 1 to 9 to each car where 9 signifies an inspection is required the most urgently.**

| Scale | Intensity | Reciprocal |
|---|---|---|
| 1 | equally preferred | 1/ |
| 2 | equal to moderate | 1/2 |
| 3 | moderately preferred | 1/3 |
| 4 | moderate to highly | 1/4 |
| 5 | highly preferred | 1/5 |
| 6 | highly to very highly | 1/6 |
| 7 | very highly preferred | 1/7 |
| 8 | very highly to the extreme | 1/8 |
| 9 | extremely preferred | 1/9 |

## VLI Maintenance Adaptations – Long Term

- **Refine the prioritization of wagons and to optimize maintenance planning based on the condition of the assets:**
  - **Restructuring preventive maintenance plans to adapt to the current condition of the wagons; and**
  - **Application of a new multicriteria methodology for maintenance planning, using cumulative risk criterion that incorporate the failure modes of the bogie and the maintenance cost (goal: minimize both)**

# VLI Maintenance Adaptations – Long Term

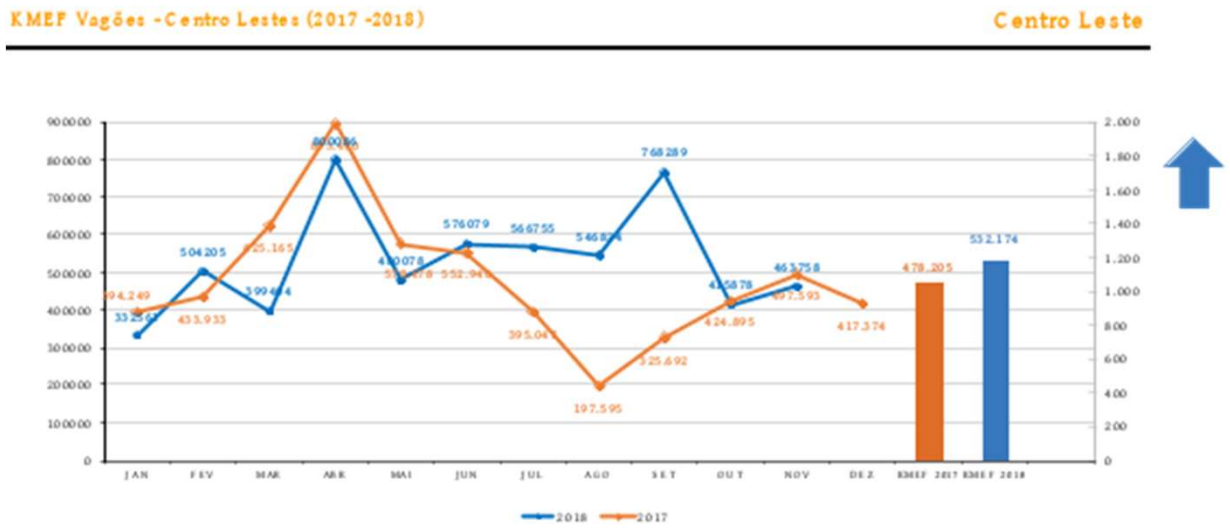
- **Each asset has a potential risk of failure which may be determined using a Failure Mode and Effect Analysis focussed on three parameters:**
  - **Severity: the severity of the fault (the higher the number the greater the risk of an accident),**
  - **Detection: how easy it is to detect the defect (the higher the number the greater the detection difficulty), and**
  - **Occurrence: the probability of a failure event occurring (the higher the number the greater the risk of occurrence).**
- **Multiplication of these three factors generates a Risk Priority Number (RPN)**

# VLI Maintenance Adaptations – Long Term

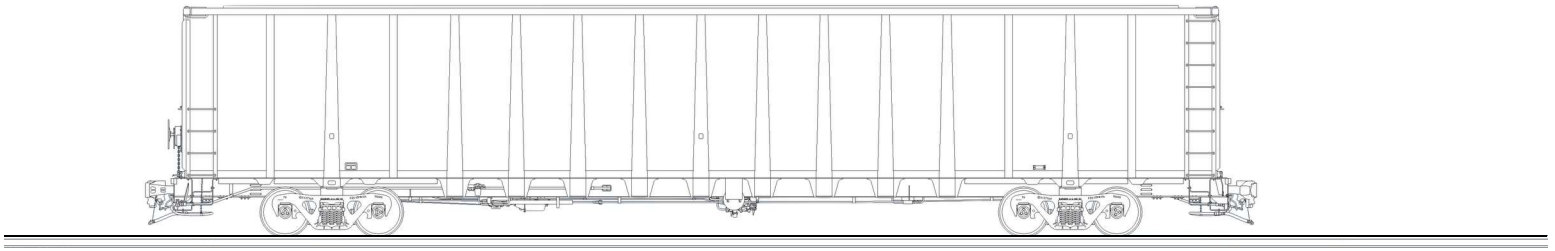
| Sistema | Item | Modo(s) de Falha | Efeito(s) Potencial(is) de Falha(s) | Gravidade (G) | Detecção (D) | Ocorrência (O) | RPN (G)*(D)*(O) |
|---|---|---|---|---|---|---|---|
| Truque | Alavanca de força | Empenamento | Descarrilamento | 10 | 4 | 5 | 200 |
| Truque | Anel de desgaste | Quebra | Ângulo de ataque fora do limite | 8 | 3 | 3 | 72 |
| Truque | Sapata de freio | Falta | Ausência de freio | 10 | 4 | 3 | 120 |
| Truque | Triângulo de freio | Contra sapata empenada / solta | Desgaste irregular de sapata | 6 | 6 | 5 | 180 |

# VLI Maintenance Adaptations – Long Term

**Over 2018 VLI achieved an increase of 11% in the reliability KPI for average kilometres between faults (in pilot corridor for long-term strategy)**



# Areas of Strategic Development



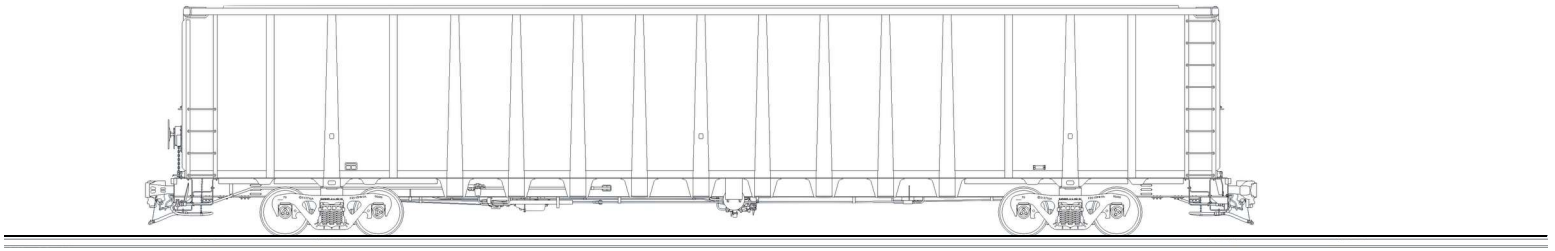
**Leading indicators**

**Identify damages as well as root cause**

**Identify maintenance-induced defects**

**Identify “Swiss Cheese” failure modes**

# Areas of Strategic Development



**Leading indicators**

**Identify damages as well as root cause**

**Identify maintenance-induced defects**

**Identify “Swiss Cheese” failure modes**

# Leading Indicators

**Identify which rolling stock is experiencing an accelerated wear regime before the majority of the damage is actually done.**

**This VLI case study found that TP defects:**

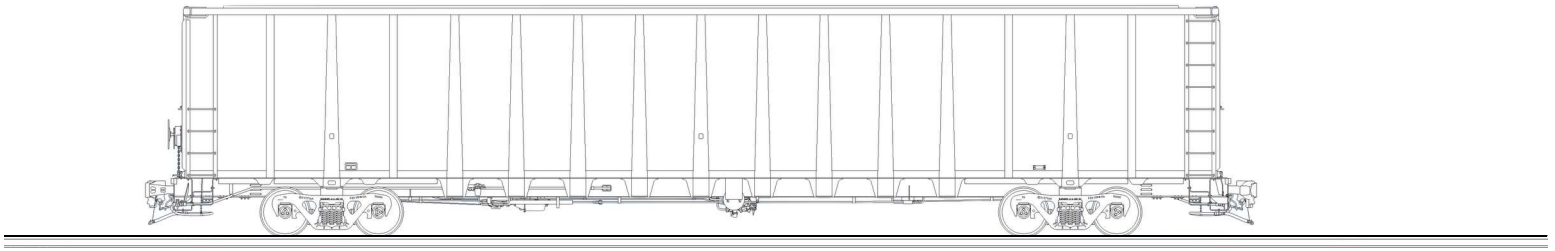
- **Typically provide 6-12 month prior warning before wheel wear accelerates rapidly**
- **A wheelset without a TP defect can degrade a flange thickness from 35 mm to 30 mm in ~160,000 km. A wheelset with a TP defect can cause the same amount of wear in only ~40,000 km (x4 times faster)**

## Leading Indicators

**Another case study looking at angle-of-attack found that such defects will develop hollowing wheel wear 3-5 times faster.**

**By enabling maintenance interventions to be more than only reactionary, significantly less material needs to be removed from wheels, and fewer bogie components need to be repaired/replaced.**

# Areas of Strategic Development



**Leading indicators**

**Identify damages as well as root cause**

**Identify maintenance-induced defects**

**Identify “Swiss Cheese” failure modes**

# Identify damages as well as root cause

**Identify defective component**

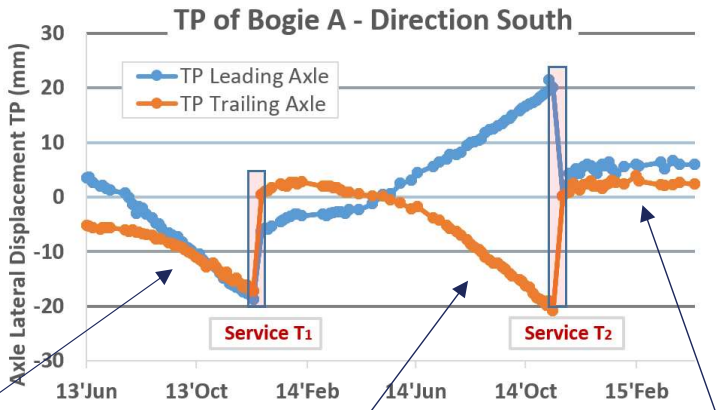
↓ *Leading indicators*

**Identify before the worst of the damage is done**

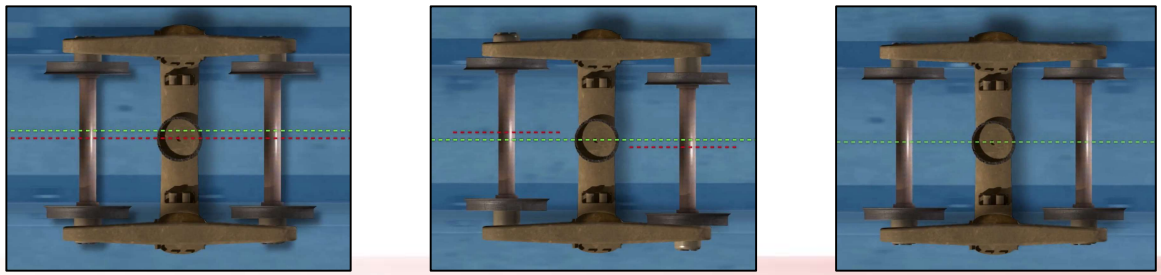
↓ *Causality*

**Identify *why* the component is defective → prevent repeat interventions for symptoms**

# Identify damages as well as root cause




***Successful***

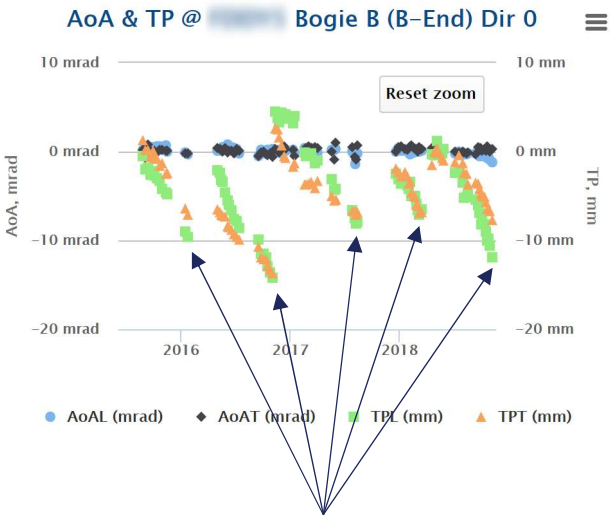


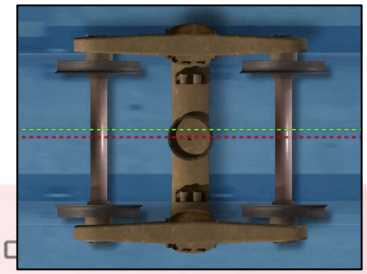
# Identify damages as well as root cause

**Wasted OPEX**

**Wasted CAPEX**

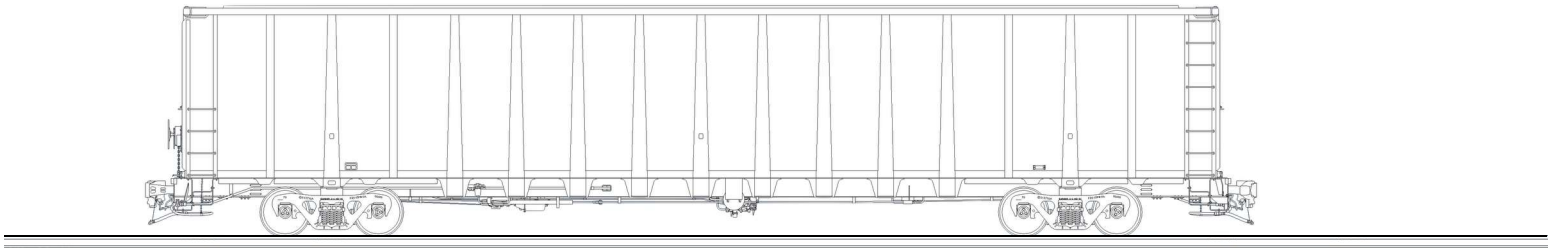
**This particular operator did not have access to TBOGI data due to data share agreements, so was unaware**



***Unsuccessful***

# Areas of Strategic Development



**Leading indicators**

**Identify damages as well as root cause**

**Identify maintenance-induced defects**

**Identify “Swiss Cheese” failure modes**

# Identify maintenance-induced defects

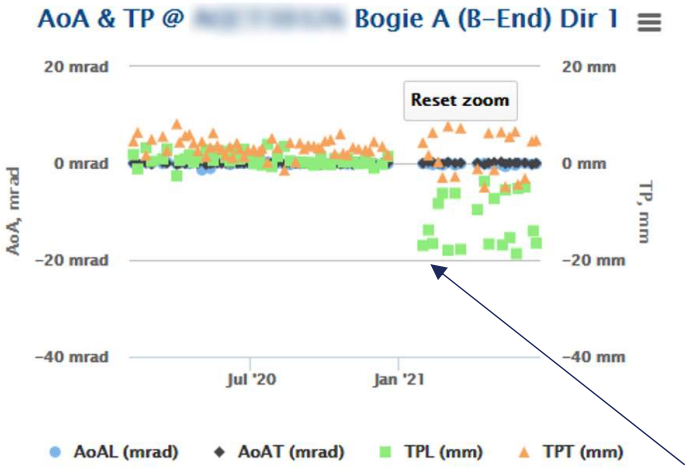
**The previous section illustrated the consequences of maintenance missing the underlying defect(s).**

**This section discusses when maintenance accidentally introduces a defect into a bogie that was not previously defective.**

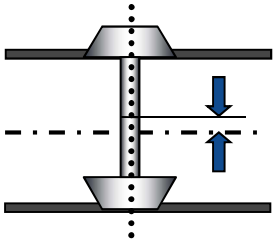
# Identify maintenance-induced defects

**Maintenance intervention introduces severe variable tracking error in leading wheelset.**

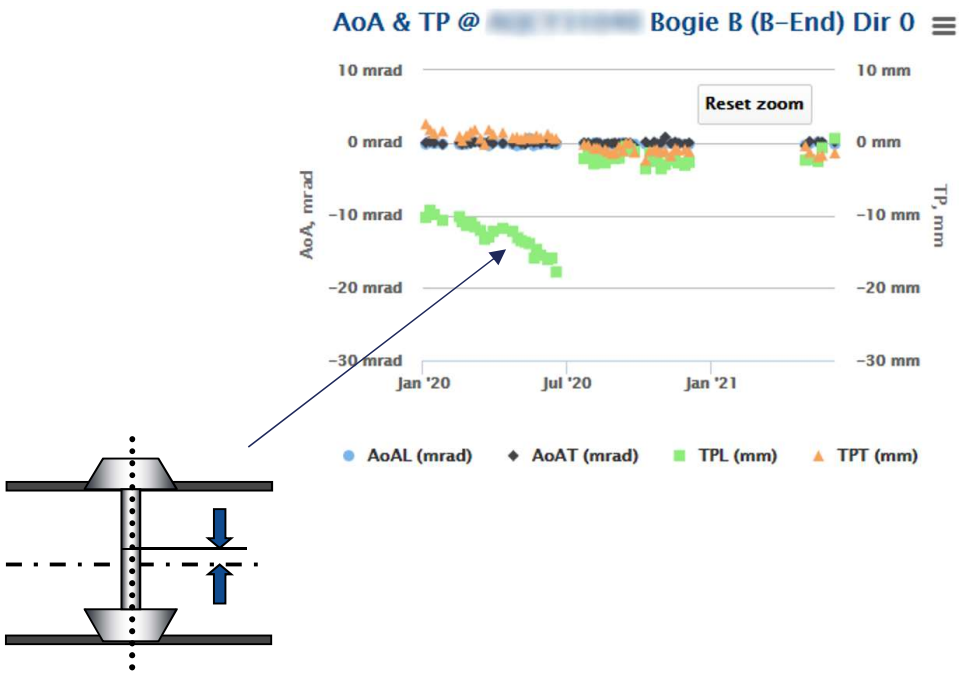
**New wheels will have thin flange within 6 months, and applies ongoing lateral stress on bearings.**




***Unsuccessful***



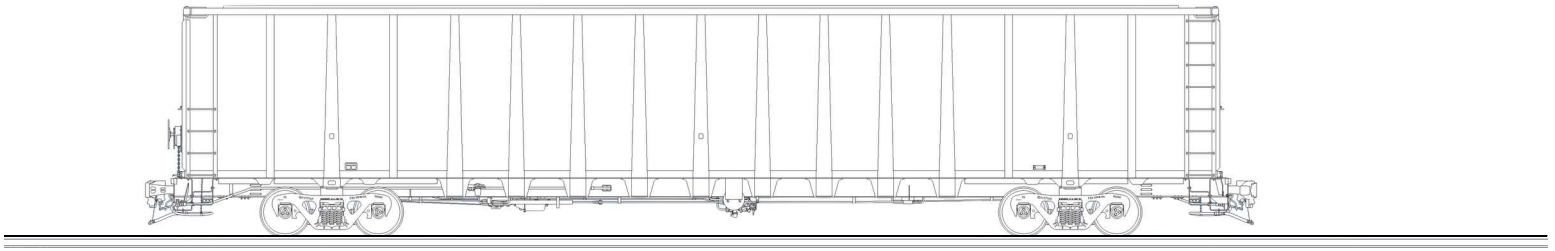
# Identify maintenance-induced defects




***Successful***

**Correct maintenance is evident**

# Areas of Strategic Development



**Leading indicators**

**Identify damages as well as root cause**

**Identify maintenance-induced defects**

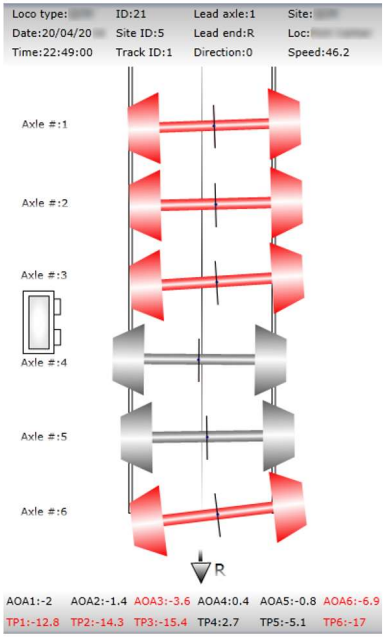
**Identify “Swiss Cheese” failure modes**

# Identify “Swiss Cheese” failure modes

**Seek to identify failure modes created not by a single critical component, but by a critical combination of component defects.**

**Individual defects can each be within tolerance, but come together to corrupt a bogie’s ability to remain on the tracks.**

# Identify “Swiss Cheese” failure modes




**There may be multiple mid-level defects, some of which out of sight, but they combine to critically compromise a bogie’s performance.**

## Conclusions – VLI Case Study

1. **The wayside measurement data corroborated the prediction made by the simulation model that TP defects create an accelerated wheel wear regime. Good similarity in the shape of the degradation curves with some variation.**

2. **TP defects typically provide a 6-12 month prior warning before flange wear accelerates aggressively.**

## Conclusions – VLI Case Study

3. **Wheelset with a TP defect will typically wear out flanges x4 times faster.**

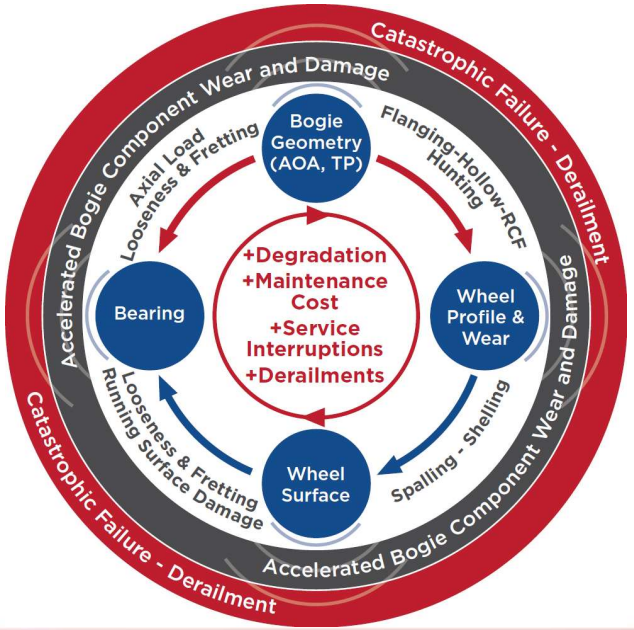
4. **Wheelset with a TP defect can experience x2 the tread wear.**

5. **The above wear rates are reflected a corresponding loss on the rail side (shown in separate studies).**

# Conclusions – VLI Case Study

**VLI have been adapting their maintenance strategies, introducing:**

- **Wayside go/no go alarms**
- **Change of schedule**
- **Creating a prioritisation ranking**
- **Introducing composite rules to decision-making, with wayside data informing maintenance practices**



# Conclusions – VLI Case Study

**This initiative by VLI is increasing maintenance efficiency and increasing the lifespan of rolling stock assets. In particular, it is improving the wheel wear rate by identifying wheels experiencing an accelerated wear regime, and introducing mechanisms to optimize maintenance resources and cost.**

# Thank you

**Speaker: Paul Bladon**

**paul.bladon@wid.ca**

VLI
Valor da Logística Integrada

WID | WAYSIDE INSPECTION DEVICES