IAVSD

21 au 25 août
Ottawa
Canada
2023

RECAP of Ottawa ICRI Workshop (IAVSD 2023 conference)

AUGUST 24, 2023

Ottawa Canada

Workshop Sponsors

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Land Acknowledgement

Ottawa is located on the traditional and unceded territory of the **Algonquin Anishinaabe people.**

The Program

- 4 sessions
- 13 presentations
- Canada, USA, Australia, Europe

start time	Thursday August 24, 2023	Presenter(s)
8:00	**Coffee served at IAVSD**	
8:30	State-of-the-Art Presentation : Improved Curving Performance Using Unconventional Wheelset Guidance Design and Wheel-Rail Interface - Present and Future Solutions	Yoshihiro Suda (The University of Tokyo), and Yohei Michitsuji (Ibaraki University)
9:30	Welcome and workshop outline	
	Session 1 **Lead: Rob Caldwell** **Topic: ICRI Field Studies Program**	
10:15	Discussion session	
10:30	**Coffee break (compliments of IAVSD)**	
	Session 2 **Topic: Friction influences on vehicle dynamics**	**Session Chairperson: Peter Klauser**
11:00	Rail vehicle curving and wheel-rail friction	Peter Klauser (Vehicle Dynamics Group LLC)
11:15	Implementation of the friction mapping concept in locomotive digital twins	Maksym Spiryagin (Central Queensland University)
11:30	Wheel-rail creep curve development using the rolling contact fatigue simulator	Alex Keylin (MxV Rail)
11:45	Field measurement of dynamic behavior with the application of TOR friction modifier on a European metro	John Cotter (L.B. Foster)
12:00	Discussion session	
12:30	**Lunch beak (compliments of IAVSD)**	
	Session 3 **Topic: Track friendly vehicles / Modeling track damage**	**Session Chairperson: Klaus Six**
13:30	Track friendly railway vehicles: aspects and challenges	Klaus Six
13:45	Universal cost model: gaps in track damage modelling	Carlos Casanueva (KTH)
14:00	High-fidelity modelling and simulation of vehicle-track interactions of transit Systems	Wei Huang (NRC)
14:15	UK track access charge model: methodology and impact on rolling stock	Yann Bezin (Huddersfield University)
14:30	Discussion session	
15:00	**Coffee break (compliments of IAVSD)**	
	Session 4 **Topic: Simulations regarding wear and RCF**	**Session Chairperson: Edwin Vollebregt**
15:30	Wheel/rail contact simulation with measured profiles	Edwin Vollebregt (Vtech CMCC)
15:45	Simplified modelling approaches for non-Hertzian and conformal wheel/rail contacts	Binbin Liu (Politecnico di Milano)
16:00	Simulation and measurement of profile evolution	Sebastian Stichel (KTH Stockholm)
16:15	Life extension for switches and crossings	Wesley Thomas (Loram Technology Inc)
16:30	Discussion session	
16:45	ICRI CONTACT benchmark	Edwin, Saeed, Binbin
17:15	**Wrap up (15 minutes)**	**Saeed Nia (NRC)**

Steering Committee

Co-chairs:

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Committee Members

Roger Lewis	Sheffield University	Kevin Oldknow	Simon Fraser University
Andy Vickerstaff	London Underground	Sylvie Chenier	National Research Council, Canada
David Fletcher	Sheffield University	Eric Magel	National Research Council, Canada
Briony Croft	Independent Consultant	Saeed Nia	National Research Council, Canada
Peter Klauser	Independent Consultant	Anders Ekberg	Chalmers University
Peter Mutton	Monash University	Carlos Casanueva	KTH University
Gordon Bachinsky	Advanced Rail Management	Adam Bevan	Huddersfield University
Klaus Six	Virtual Vehicle	Binbin Liu	Milan Politech
Edwin Vollebregt	Loram	Sebastian Stichel	KTH University

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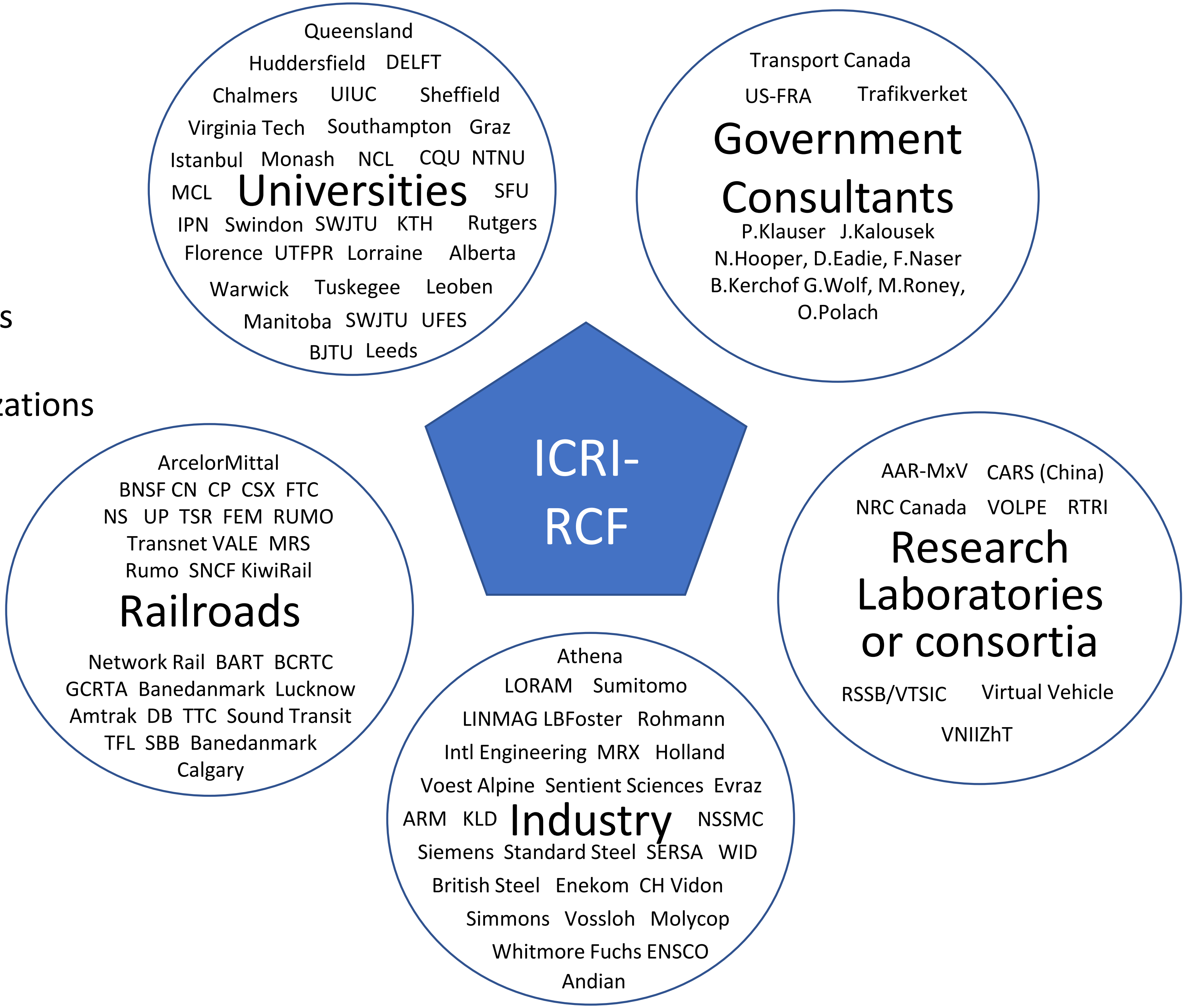
200+ organizations



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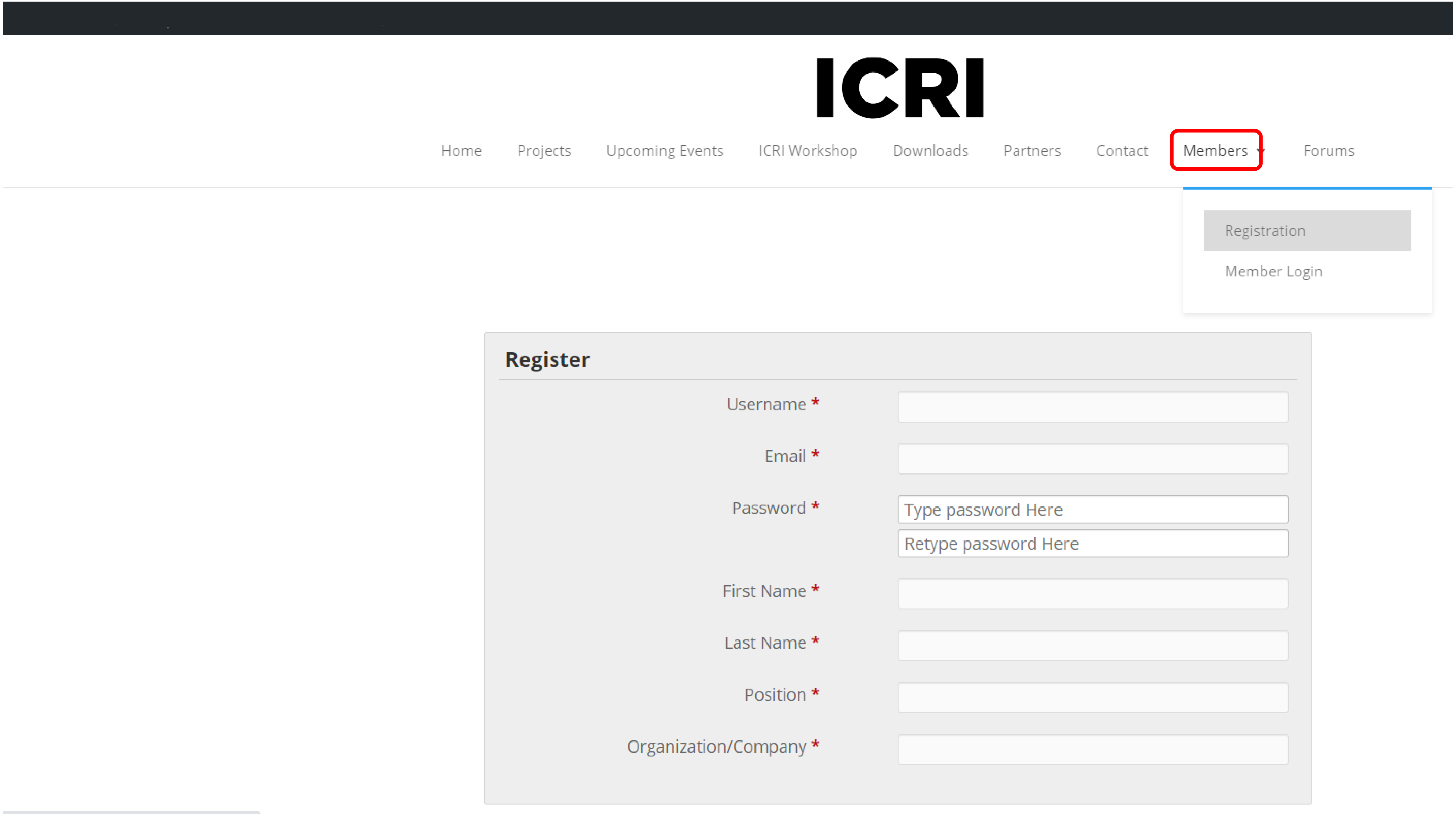

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- Friction Studies
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Melbourne 2022 ICRI Mini Workshop downloads

- Workshop Presentations

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Ottawa 2022 ICRI Workshop downloads

- Workshop Program
- Keynote by Dan Hampton / CSX
- Presentations Day 1 (zip file)
- Presentations Day 2 (zip file)
- Presentations Day 3 (zip file)

Vancouver 2019 ICRI workshop downloads

- Presentations Day 1 (zip file)
- Presentations Day 2 (zip file)
- Presentations Day 3 (zip file)
- Summary Document

ICRI Webinar on Experimental study on wear and RCF damage of wheel/rail materials under complex environment conditions (13APR22)

- Presentation
- Meeting recording

ICRI Webinar on Analytical Estimation of Impact Forces Due to Abrupt and Rapid Changes in Track Profile at Rail Ends and Turnout Crossings (02MAR22)

- Presentation
- Meeting Recording

ICRI Webinar on Long- and Short-term effect of Top of Rail Friction Modifiers (TORFM) on Traction (26JAN22)

- Presentation
- Meeting Recording
- JRC2021-1050_TORFM Study_Virginia Tech
- Test Rig Video

ICRI Webinar on Quantifying friction modifier effects on roughness and corrugation growth (14DEC21)

- Presentation

https://www.icri-rcf.org/events/

28th IAVSD International Symposium on Dynamics of Vehicles on Roads and Tracks. August 21-25, 2023, Ottawa, Canada

The IAVSD Symposium on Dynamics of Vehicles on Roads and Tracks is a leading international symposium bringing together researchers, scientists and engineers from academia and industry in the field of ground vehicle dynamics to present and exchange their latest ideas and breakthroughs.

The biennial IAVSD Symposia have been held in internationally renowned locations and this event will, for the second time, take place in Canada. The organisers of this Symposium are the National Research Council of Canada, Virginia Tech and Carleton University.

The Symposium will also offer an opportunity to participants to visit interesting places and to observe road and rail operations and advanced technologies in National Capital Region of Canada.

For more information please see: IAVSD 2023

ICRI Ottawa Workshop at IAVSD. August 24, 2023, Ottawa, Canada

The ICRI presents a one-day workshop in Ottawa during the IAVSD conference. For more Information on the workshop please visit here.

For more information on IAVSD please see above.

12th International Heavy Haul Conference (IHHA 2023). 27 – 31 August 2023 in Rio de Janeiro, Brazil

The International Heavy Haul Association (IHHA), in partnership with MRS Logistics railway, will be hosting its 12th International Heavy Haul Conference, on 27 – 31 August 2023 in Rio de Janeiro, Brazil.

The Theme for this conference is: Application of Heavy Haul Innovations for a Sustainable World.

Upcoming ICRI workshops

September 18-20, 2024: 2-1/2 day workshop in Vienna Austria

Session 1

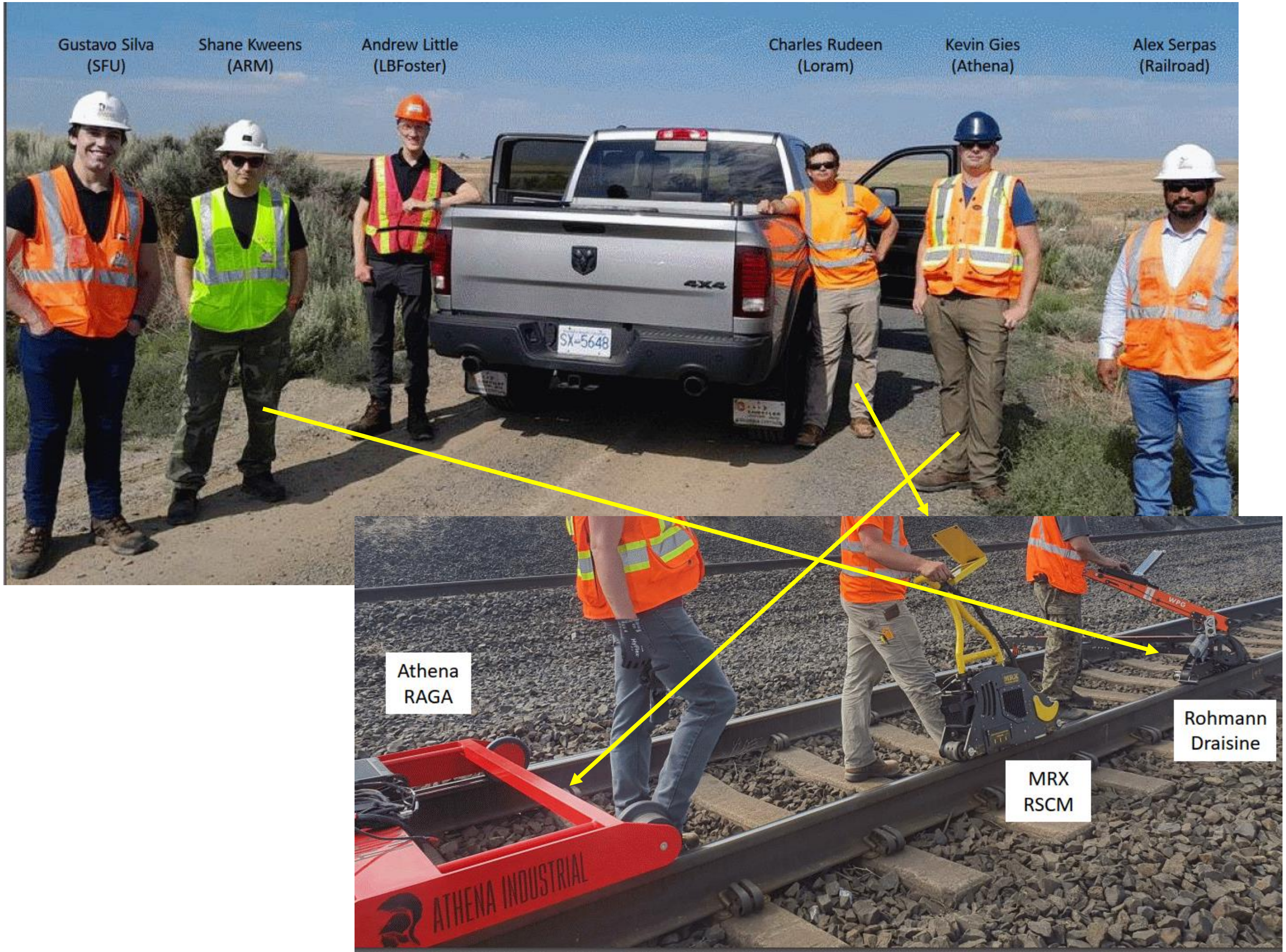
Robert Caldwell, NRC, Canada: ICRI Field Studies Program

ICRI Field Studies

- Outline:
  - Review of program plan, examples of data collected, next steps
- Technical Goals:
  - Develop relationships between
    - Visible surface damage and measured depths
    - Surface Damage and risk
  - Methods for incorporating new inspection technologies into maintenance
  - Establish best practice for grinding of new rail
  - Characterize friction conditions
  - Understand rates of crack initiation and growth
  - Develop and validate models of wear and surface fatigue

Inspection Locations

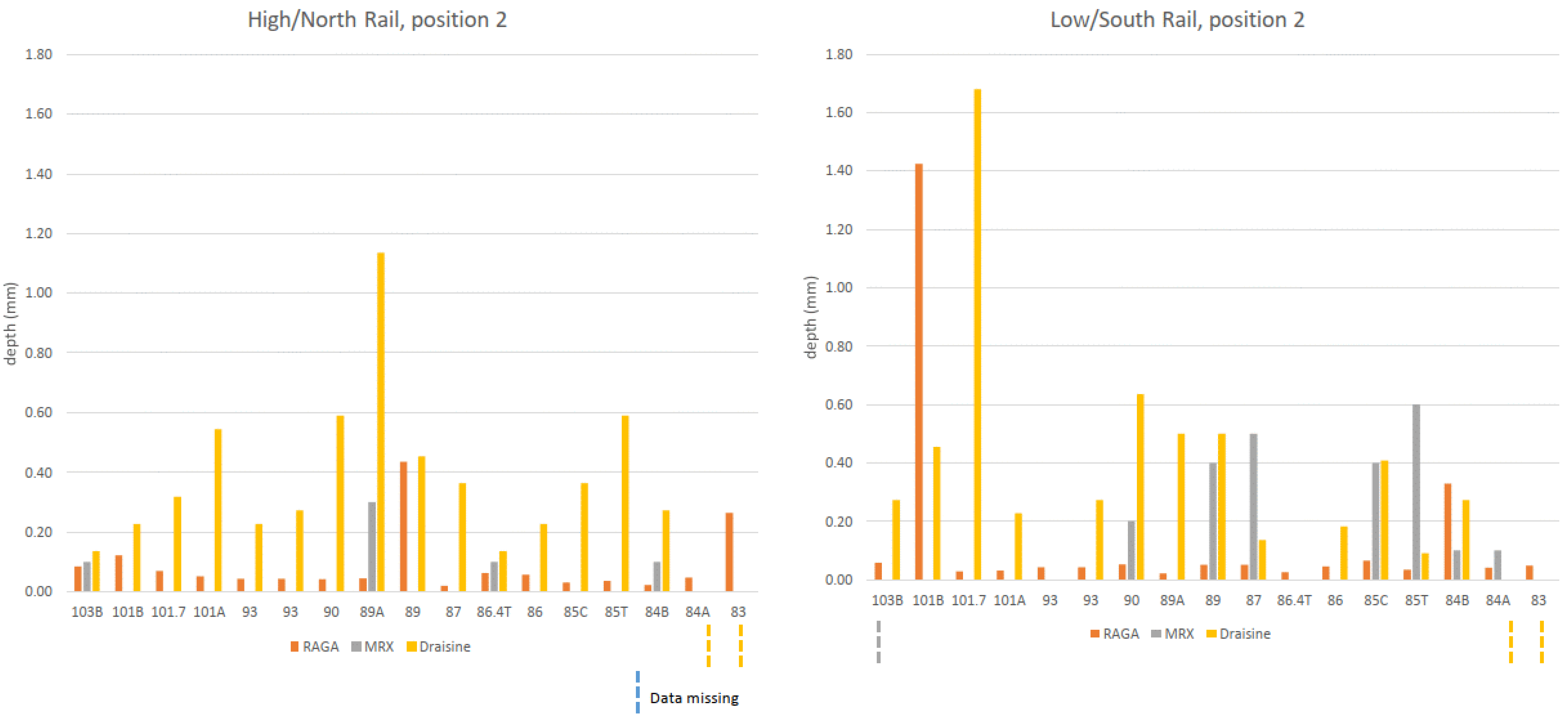
	MP		Track	DOC	Curve Rail Branding		RCF on rails	
					Hi or North	Low or South	Hi	Low
1	103B	Curve	Single	6.50	141RE ERMS 2022	141RE ERMS 2022	light in mid-gauge	clean
2	101B	Curve	Single	3.00	141RE ERMS 2022	141RE VT JFE 2008	Not noted	clean
3	101.7	TAN4	Single	tangent	136RE ERMS 2020	136RE ERMS 2020	light GCC	light GCC
4	101A	Curve	Single	6.83	141RE ERM 2021	141RE VT ERMS 2010	Light cracking	very light cracking
5	93	Curve	M2	1.00	136-10 HH VT NIPPON 1992	136-10 HH VT NIPPON 1992	clean	clean
6	93	Curve	M1	1.00	1360 RE VT CF&I 1997	1360 RE VT CF&I 1997	Light GCC	clean
7	90	Curve	M1	6.00	141RE ERMS 2021	141RE ERMS 2021	light gcc	moderate RCF
8	89A	Curve	M1	4.50	141RE ERMS 2022	141RE VT JFE 2011	Light cracking	moderate cracking
9	89	Curve	M1	6.50	141RE ERMS 2021	141RE VT JFE 2017	moderate RCF	light RCF
10	87	Curve	M1	6.32	141RE ERMS 2017	141RE ERMS 2021	Light cracking	Light cracking
11	86.4T	TAN3	M1	tangent	1360 RE VT CF&I 1996	1360 RE VT CF&I 1995	No RCF	No RCF
12	86	Curve	M1	4.10	141RE ERMS 2021	141RE VT JFE 2009	Light GCC, TOR light spalling	Light RCF
13	85C	Curve	M1	4.10	141RE ERMS 2022	141RE ERMS 2021	**new rail**, light GCC	mod RCF, mis
14	85T	TAN2	M1	tangent	136 - 10 CC BETH STEELTON 1996	136 - 10 CC BETH STEELTON 1996	No RCF	No RCF
15	84B	Curve	M1	3.00	141RE ERMS 2022	141RE VT JFE 2009	**new rail**, very light gcc	mod TOR, mis
16	84A	Curve	M1	4.33	141RE ERMS 2018	141RE VT JFE 2013	Moderate GCC, TOR light spalling	moderate spalling
17	83	Curve	M1	4.32	141RE ERMS 2018	141RE ERMS 2020	Light cracking, light spalling	Mild cracking



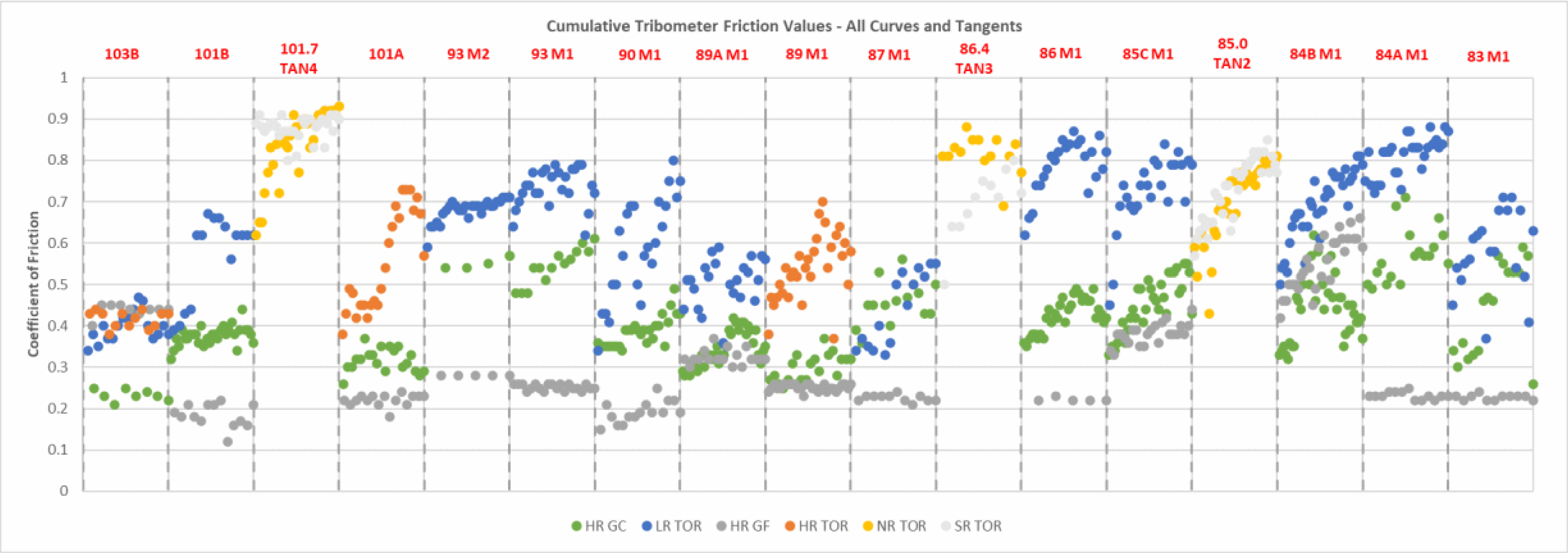
Also:
Eric Magel (ARM)
Douglas Nikl (Evraz)
Marco Santoro (LB Foster)

3 field trips completed
June, Sep, Nov

Initial comparisons



Tribometer Results



Next Steps

- Depositing data to a common site
  - Photographs
  - Profile measurements
  - RSCM (MRX)
  - Draisine (Rohmann)
  - Raga (ATHENA)
  - Tribometer (LBFoster)

RCF growth and wear rates
Economic analysis
Magic Wear Rate
Update Atlas of Rail Surface Defects

- Preliminary analysis for 2 test sites.

Discussion

Session 2

Wheel-Rail Friction and (Steady-State Curving)

Peter Klauser – pklauser@vehicle-dynamics.com
Vehicle Dynamics Group LLC

ICRI Workshop • 24 August 2023 • IAVSD 2023 • Ottawa, Canada

Vehicle Dynamics Group LLC

Wheel-Rail Friction and (Steady-State) curving

Reality versus Model

Reality

- Contamination (rust, organic material, moisture, etc.)
- Friction modifiers and lubricants

= ?

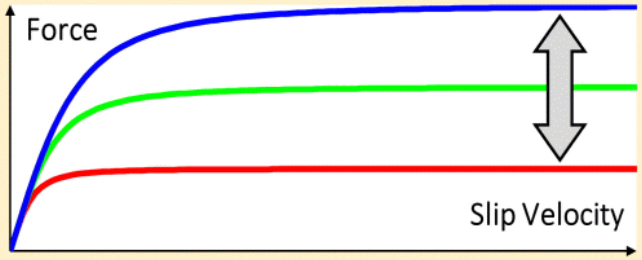
Model

- FASTSIM
- CONTACT
- Polach's Method
- …

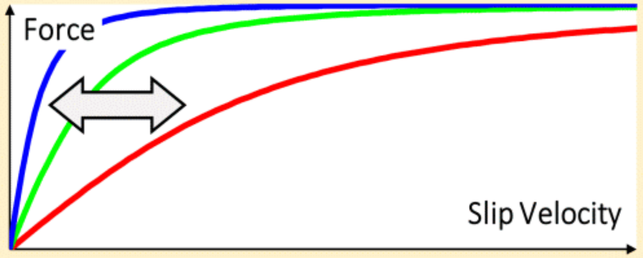
+

Adjustments

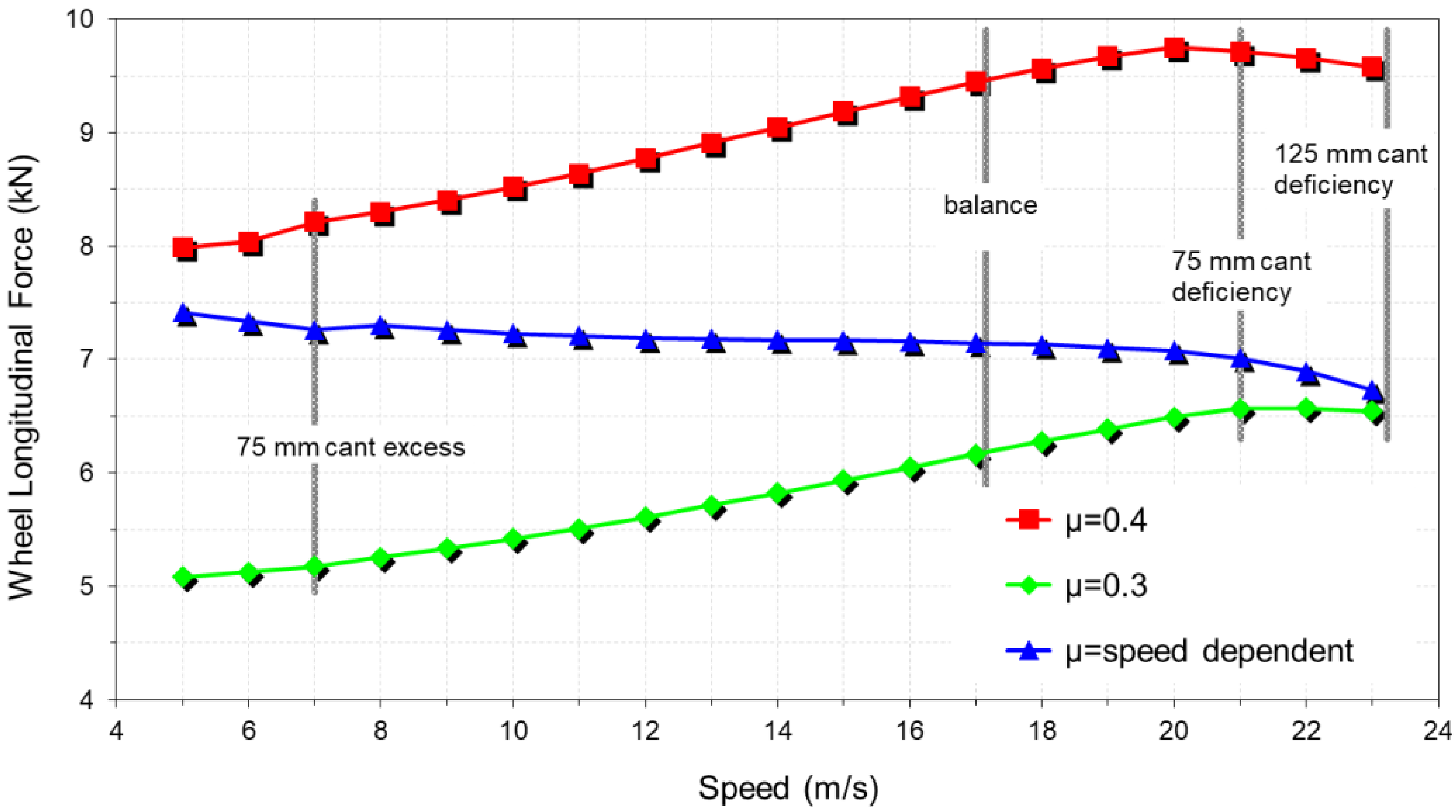
- Friction Coefficient



- "Kalker" Factor



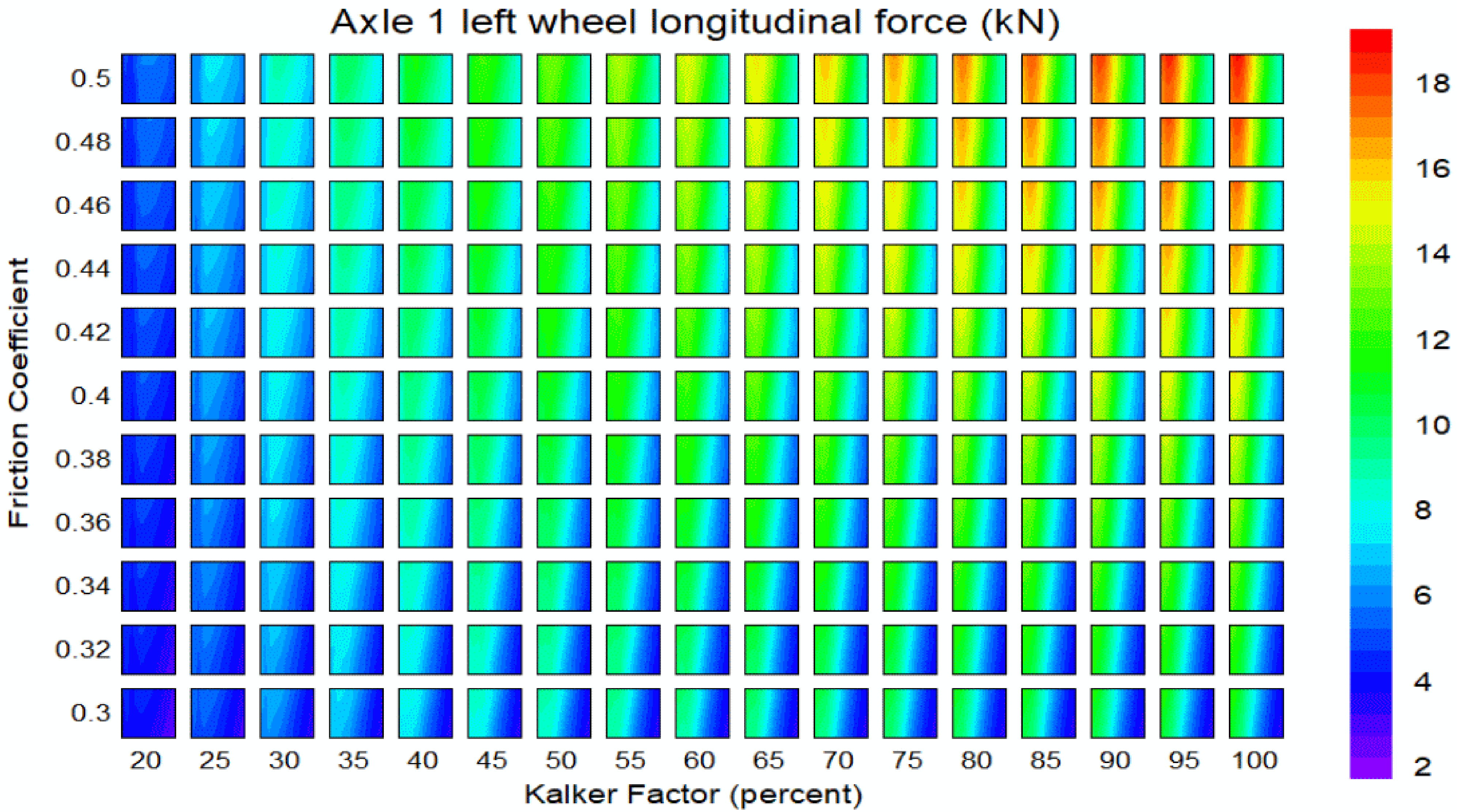
Leading Axle Low Rail Wheel Longitudinal Force for 300-meter Curve



Can this trend be observed in steady-state curving test data ?

Vehicle Dynamics Group LLC

Leading Axle Outside Wheel Longitudinal Force



Same data, different view

At low values, Kalker factor is significant

Friction coefficient is otherwise more important variable

Vehicle Dynamics Group LLC

Some Conclusions

- Interaction between steel wheel and steel rail is complicated
- Theoretical representations of this behavior range from simple to complex
- Users of these methods have limited methods for adapting models to “real world” conditions between wheel-rail interface
- There are plenty of practical measurements leading to unexplained results
  - Effect of vehicle velocity
  - Effect of nominal static load
- Very clear that wheel-rail interface conditions significantly influence vehicle behavior
- We are not done yet …

More conferences and workshops in future !

Discussion

Implementation of the friction mapping concept in locomotive digital twins

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Centre for Railway Engineering
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m.spiryagin@cqu.edu.au

CQUniversity AUSTRALIA

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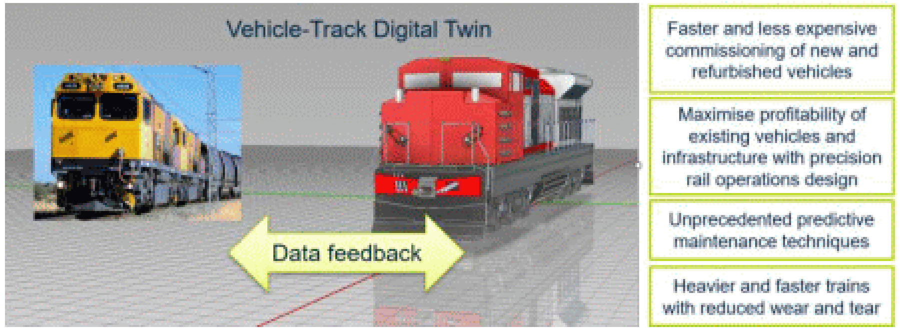
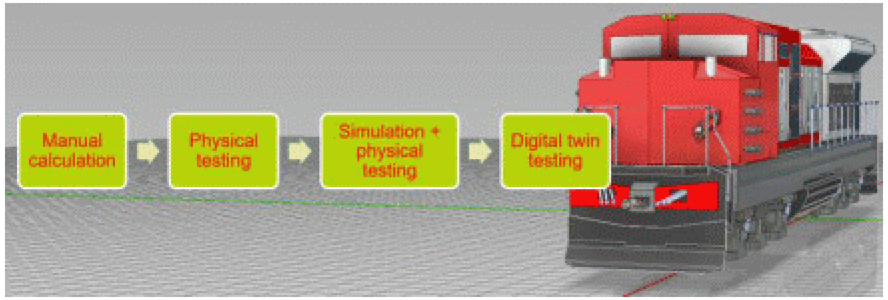
cqu.edu.au

INTRODUCTION

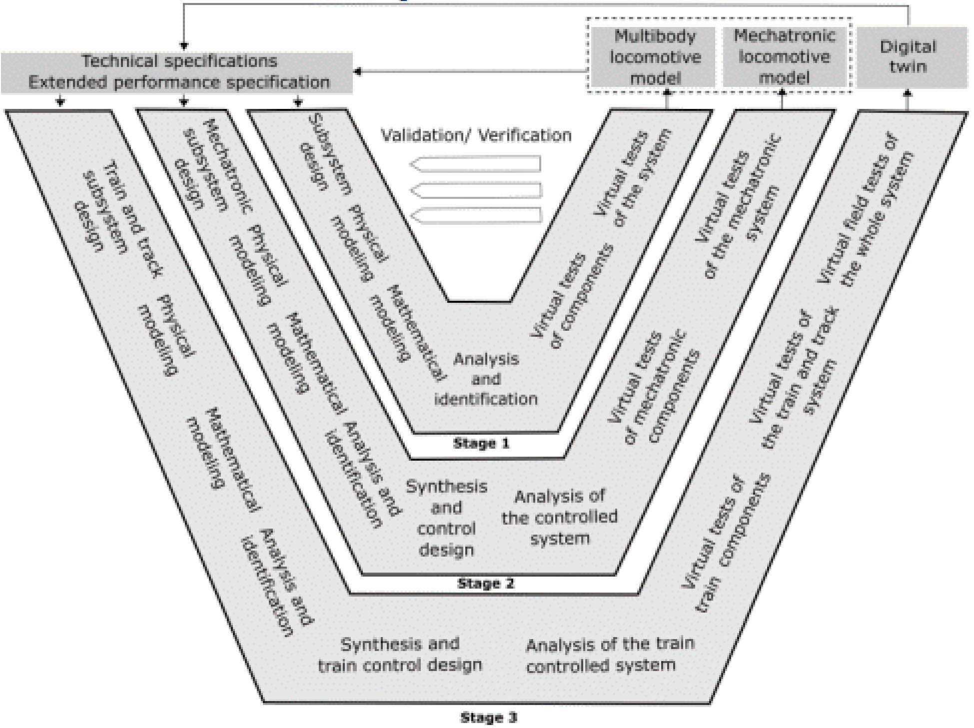
Concept of forming of knowledge from DT implementation



Simplistic steps to build physics-based DT

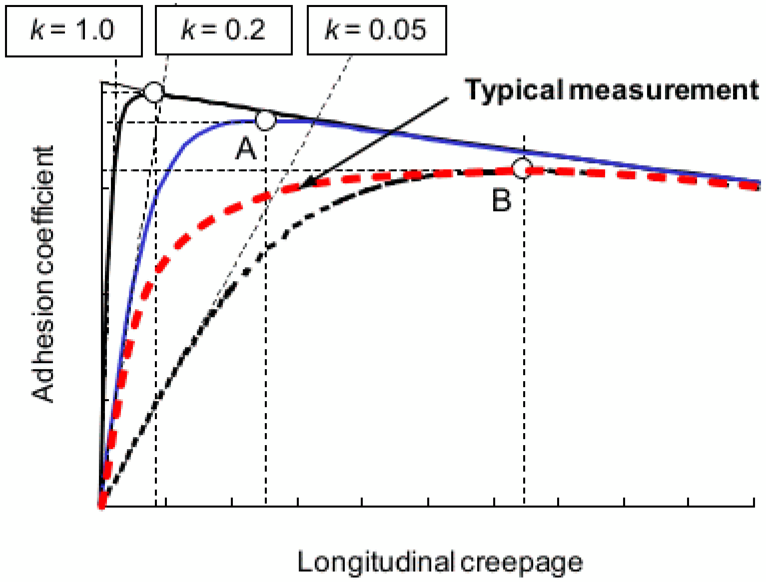


Several integration design stages for the development of the DTs



M. Spiryagin, Q. Wu, O. Polach, et al. Problems, assumptions and solutions in locomotive design, traction and operational studies. Railway Engineering Science, 2022, vol. 30, pp. 265–288.

Modelling of creep force characteristic using falling friction coefficient and different reduction factors k



M. Spiryagin, O. Polach, C. Cole. Creep force modelling for rail traction vehicles based on the Fastsim algorithm. Vehicle System Dynamics, 2013, vol. 51, no. 11, pp. 1765-1783.

Tribometer operational runs on the railway line with the following measurements:

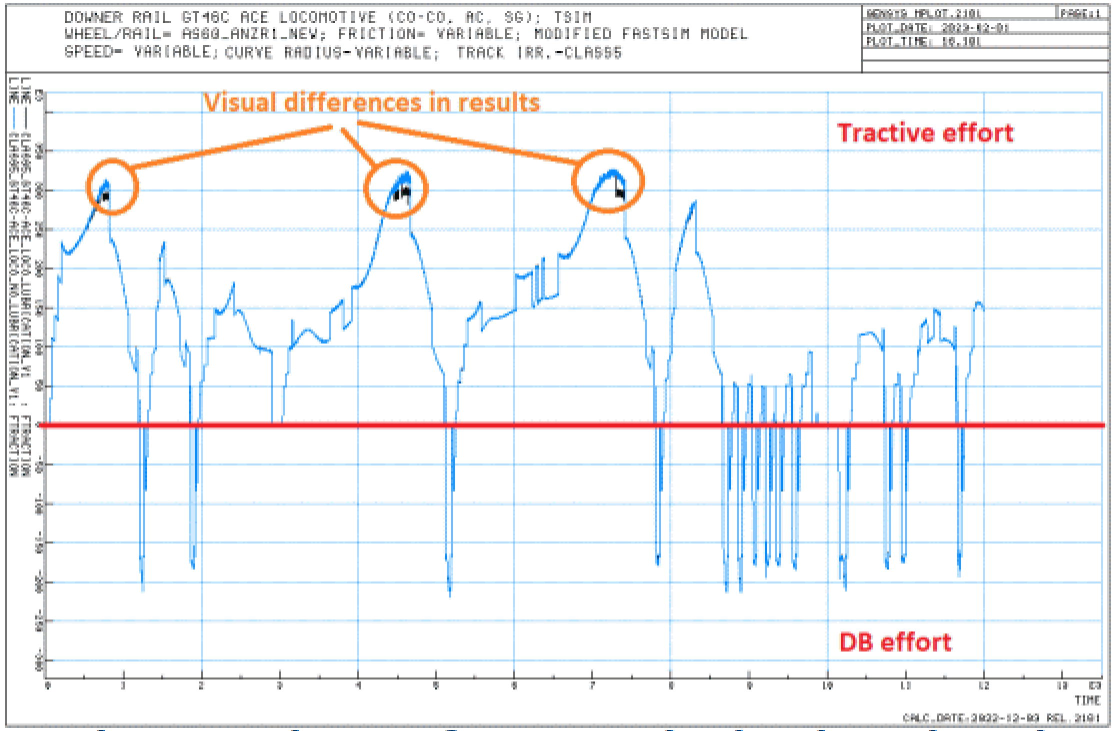
- GPS;
- Rail profile;
- Three contact locations;
- Roughness;
- Environment conditions;
- Slip (variable parameter);
- Angle of attack;
- Contact forces.

Table 1: Most common contact model combinations to study traction

Approach complexity	Friction model	Tangential problem
Simplified	$\mu = \mu_s((1-A)e^{-Bv} + A)$ [19] μ_s is the maximum coefficient of friction, A is the ratio of the limit friction coefficient at infinity slip velocity to the maximum friction coefficient, v is the sliding velocity (also called the magnitude of the slip/creep velocity vector) and B represents the coefficient of exponential friction decrease, s/m.	Polach
Compound		Modified Fastsim
Complex		ASIM, Extended Contact

APPLICATION OF FRICTION MAP IN LOCOMOTIVE DT STUDY

- A typical standard gauge 136 tonne heavy haul locomotive with a Co-Co wheel arrangement has been used.
- A 192 km long heavy haul track with gradients and curvature was used for the case study.
- The train consists of four locomotives and 160 loaded wagons.



Locomotive performance in the time-domain (blue line – non-lubricated dry track, black line – track with lubricated curves)

CONCLUSION

- The concept of friction mapping has been presented and the proof of its applicability in the DT study was shown.
- The results show that the DT technique is affected by friction mapping, and it is worth making a transition from a conceptual design of the delivery of a railway line friction map to actual developments.
- There is no easy solution to implement it quickly considering various applications in different train and locomotive consist configurations and operational scenarios.

Discussion

Wheel-Rail Creep Curve Development Using the Rolling Contact Fatigue Simulator (RCFS)

Alexander Keylin, Nicholas Wilson
Alexander_Keylin@aar.com Nicholas_Wilson@aar.com

ICRI Workshop, 2023-08-24

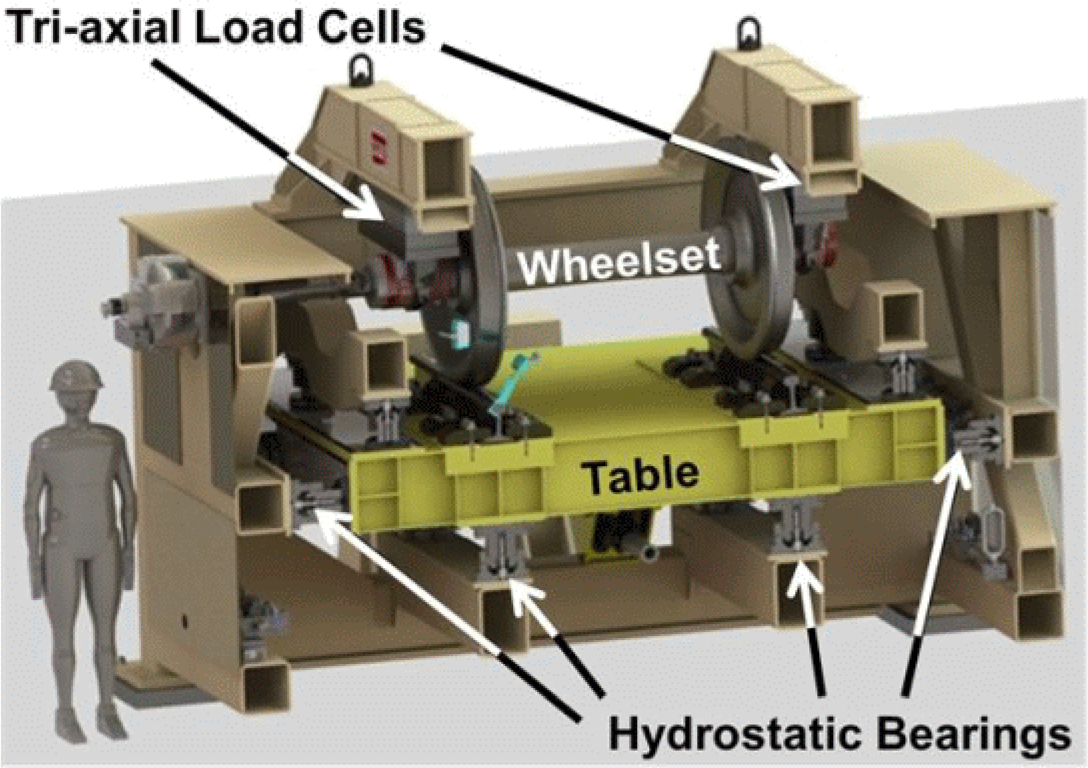
MxV Rail
350 Keeler Parkway | Pueblo, CO 81001
A subsidiary of the Association of American Railroads

Methods for W/R Friction Measurement

- **Pendulum tribometers**
  - Only measure COF, not creep curve
- **Portable tribometers**
  - Typically control longitudinal creepage
  - Effects of scaling
- **Instrumented wheelsets (IWS)**
  - Difficult to measure creepage accurately
- **Locomotive traction motors**
  - Difficult to measure creepage accurately
  - Only longitudinal creepage is controlled
- **Twin disk machines and roller rigs**
  - Typically control longitudinal creepage
  - Effects of scaling
  - Contact patch shape affected by roller/disk radius

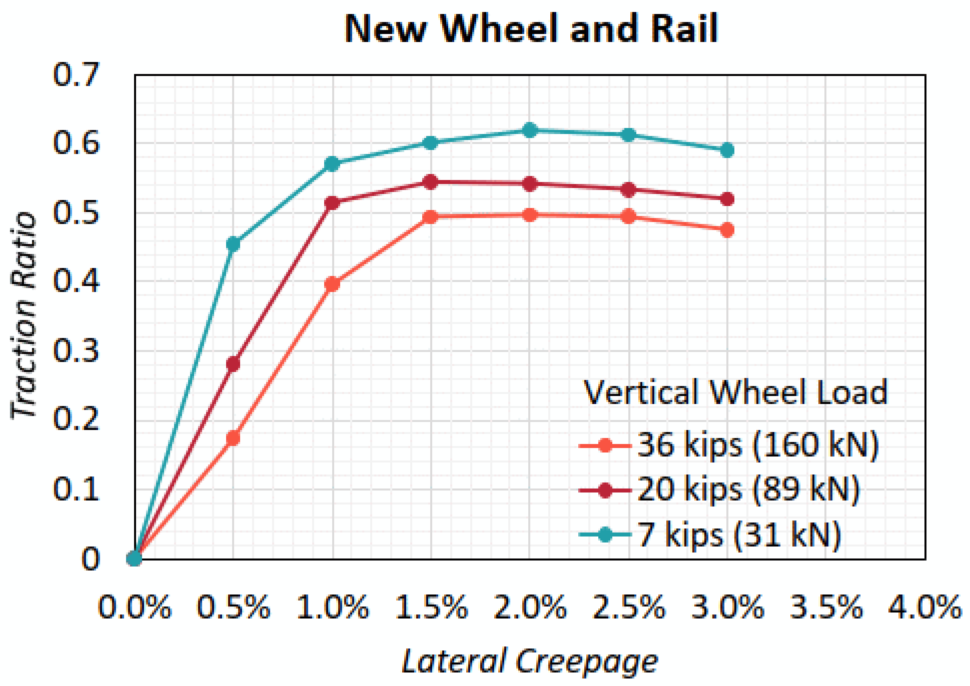
RCFS Design and Operation

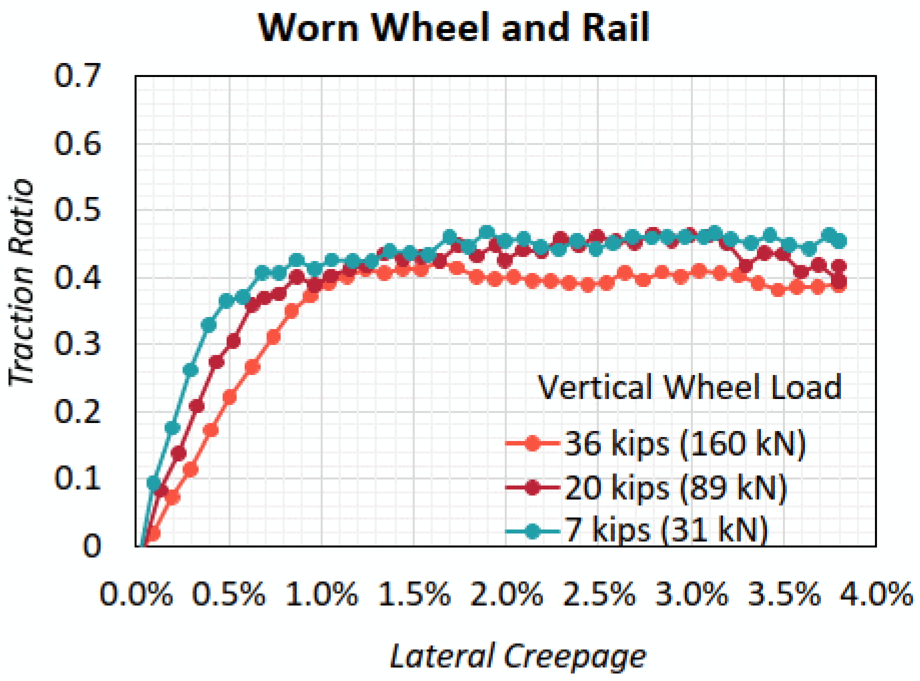
- **A full-scale testing machine replicating wheel-rail conditions in revenue service**
  - No scaling factors required for contact patch pressure, mass/inertia, time, velocity, forces, etc.
  - Can test new and worn wheelsets and rails from the field
  - No distortion of contact conditions due to roller curvature
  - Control of friction conditions (third body layer application)
  - Precise control of wheel/rail relative position, orientation, and velocity
  - Accurate measurement of wheel/rail forces, positions, contact patch dimensions



Results: Lateral Creep Curves vs. Vertical Wheel Load

- **Maximum W/R traction ratio <u>increases</u> as vertical wheel load decreases**
  - Effect is more pronounced for new wheel and rail than for worn wheel and rail
- **Initial creep curve slope <u>increases</u> as vertical wheel load decreases**
  - Consistent between new and worn wheel and rail





Discussion

- **Findings**
  - Peak traction ratios (COF) for dry and wet contact conditions are within expected range
  - Decreasing contact stress → increasing curve slope, increasing COF
  - Lower COF for worn wheel and rail condition
    - Effects of surface hardness and roughness
  - Falling friction (decrease in COF at high creepages) not observed
    - Creepages are likely not high enough
- **Challenges**
  - Longitudinal creepage is difficult to control and measure accurately
  - High longitudinal creepages are difficult to produce
- **Possible Directions for Future Work**
  - Custom machined wheel and rail samples to produce higher creepages
  - Various third body layer conditions (sand, TOR-FM)

Discussion

LBFoster

Field measurement of Dynamic Behavior with the Application of TOR Friction Modifier on a European Metro

ICRI Workshop

August 24th 2023

Trial Background

- In 2006, Azienda Trasporti Milanesi (ATM) metro was experiencing problems with high-speed stability, particularly at speeds near operation limits (80 km/hr)
- ATM has observed that stability varies with temperature and humidity. As these parameters have a significant impact on rail head friction, it is possible that variations in natural friction levels are the cause of the changes in stability.
- ATM has also noted that train running temperatures affect hunting intensity
  - "Cold" trains (i.e. just started operation) do not tend to hunt
  - "Warm" trains (i.e. warmed up from gear running) have increased hunting propensity

Dynamic Rail Head Friction Conditions (MBTA)

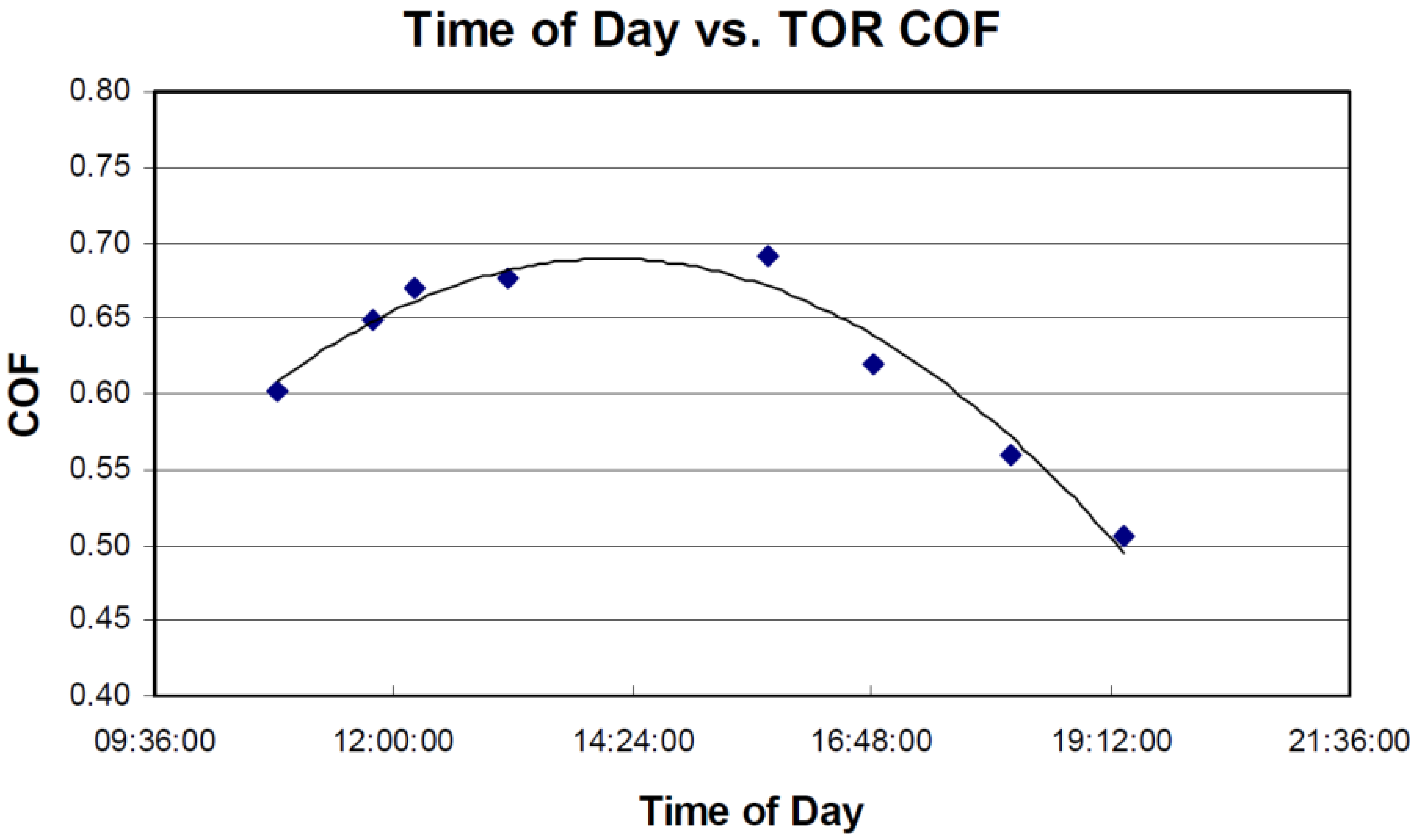


Figure 3: COF Readings from Day 4

Test Results – Axle Box Acceleration - Run 2 (85 km/h)

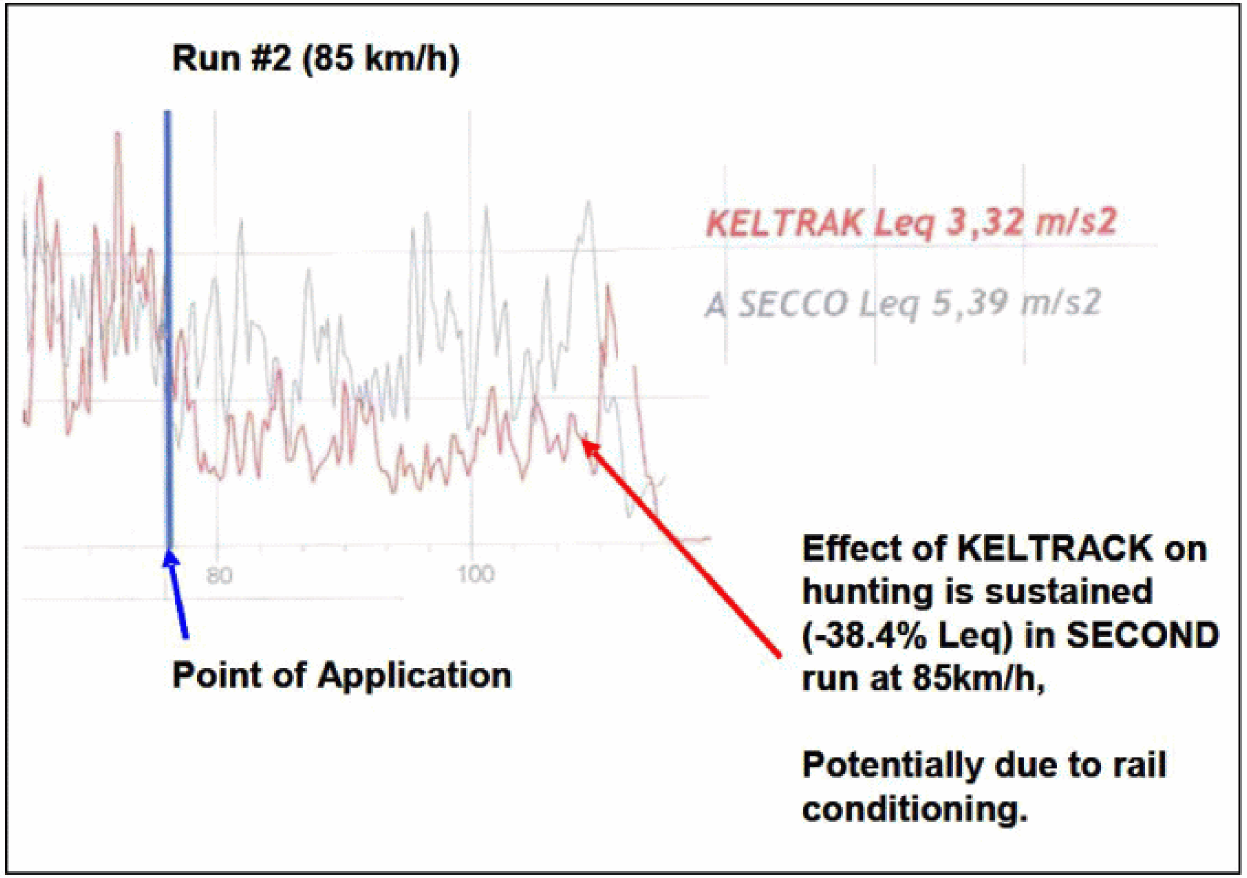


Figure 7. Detailed view of Test Run #2, conducted at 85 km/h

> Additional rail conditioning in the test area with the passage of 144 - 216 additional axles,

> Sustained reduction in acceleration measurements

> Observed acceleration signals upstream of applicator system appear to be roughly equivalent to Dry Rail values providing further support for the effects of friction modifier application seen in test run #2

BHP – Iron Ore Results

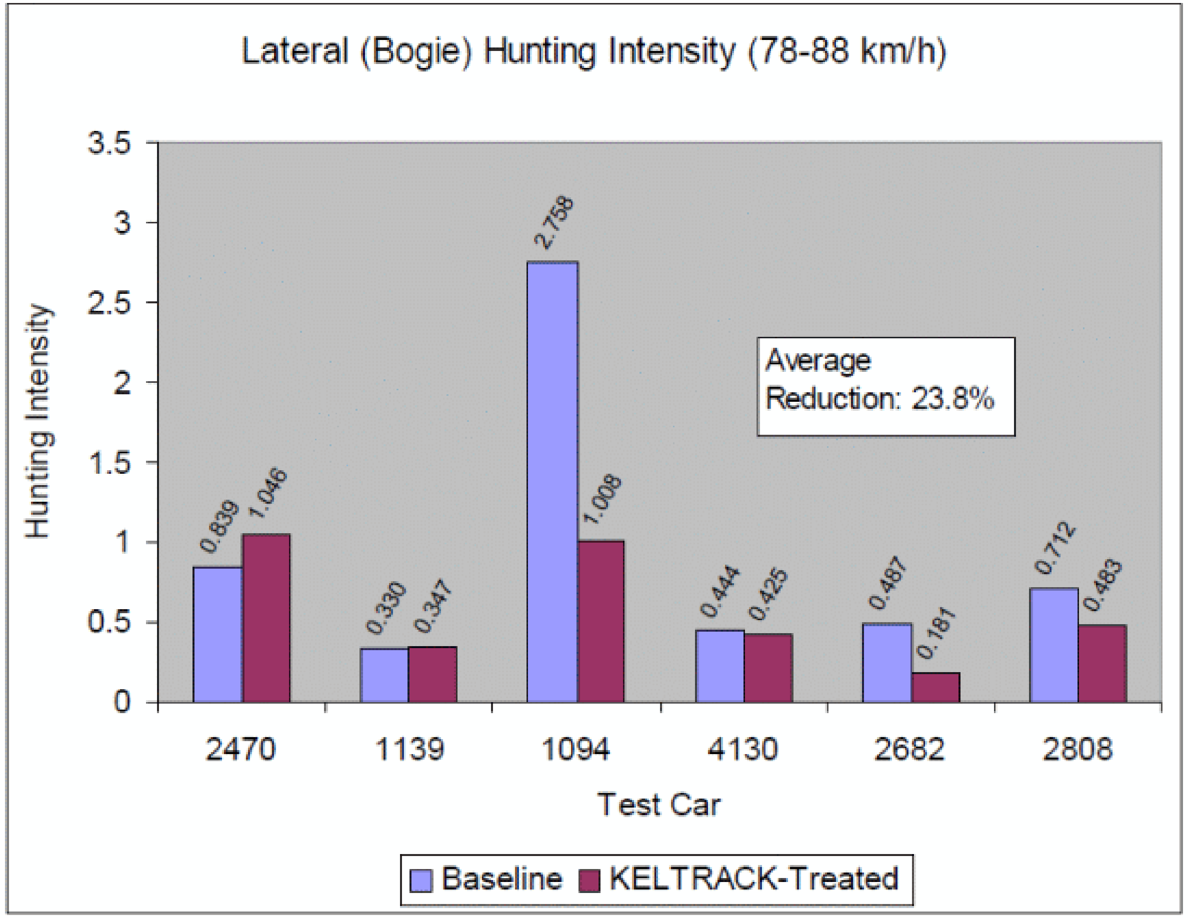


Figure 10. Lateral Bogie Hunting Intensity measurements from BHP-IO testing at 78-88 km/h.

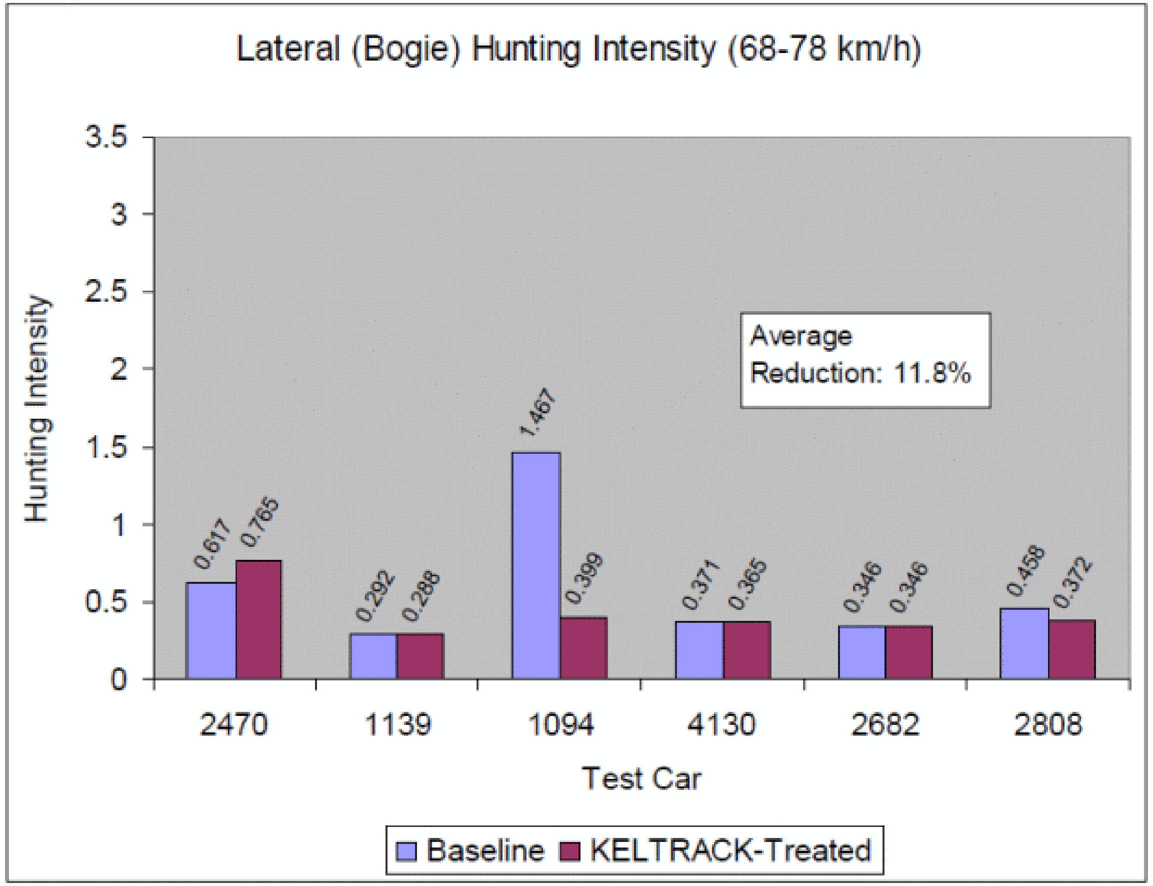


Figure 9. Lateral Bogie Hunting Intensity measurements from BHP-IO testing at 68-78 km/h.

Testing included the effects of wheel/rail profile combinations, bogie maintenance and the application of liquid HPF (i.e. KELTRACK) on hunting behaviour of vehicles in tangent track

S. Marich, P. Bartle, R. Bowey, A. Cowin, G. Offerins and M. Moynan, (1999) Assessment of Wheel/Rail Interaction and Vehicle Dynamics at BHP Iron Ore, Proceedings of the IHHA'99 STSConference,Session 2, Invited Papers, 67-77.

Discussion

Session 3

ICRI Workshop

Session 3: Track Friendly Vehicles / Modelling Track Damage

Klaus Six
Key Researcher

IAVSD 2023, Ottawa, Canada

24-08-2023

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Federal Ministry Republic of Austria Climate Action, Environment, Energy, Mobility, Innovation and Technology
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SFG

Virtual Vehicle Research GmbH has received funding within COMET Competence Centers for Excellent Technologies from BMK, BMAW, the Province of Styria (Dept. 12) and the Styrian Business Promotion Agency (SFG). The Austrian Research Promotion Agency (FFG) has been authorised for the programme management.

Track Damage

system	physical quantities	damage mechanisms	damage patterns	maintenance actions	Costs per unit
vehicles	contact stresses/forces	wear	change of rail profile	grinding/milling	cost/m
track	creepages	RCF	head checks	tamping	cost/unit
operation	wear number Ty	massive plastic deformation	rail corrugations	rail renewal	
friction management	dyn. vert. forces	thermal material phase change	squats/studs	track renewal	
environmental conditions	ballast pressure	material fatigue	fatigue of rail pads	renewal of sleepers	
...	ΣY-forces	ballast settlement	track irregularities	renewal of fastening systems	
	....	ballast breakage	damage on sleepers		
		flow of subsoil	...		
		...			

material properties

Different operators might have different damage patterns?

Track Damage Modelling

Context of track damage model use?

- track access charges
- tenders
- maintenance planning
- detailed understanding for certain damage patterns
- …

Expectations on prediction quality might be different? → model complexity?

Track Damage Model Complexity → e. g. Rail RCF

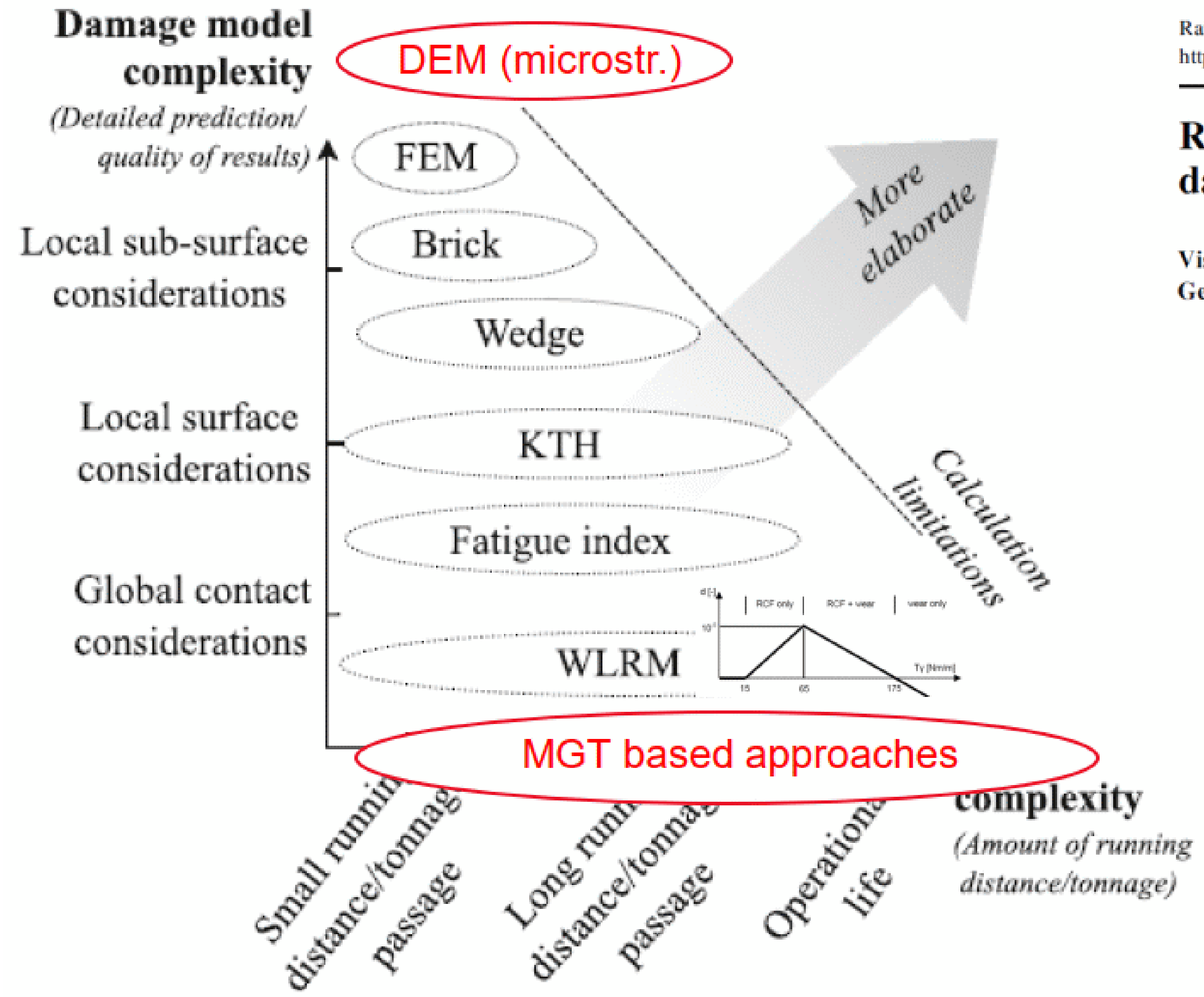


Fig. 1 Different approaches for quantifying RCF damage

Rail. Eng. Science
https://doi.org/10.1007/s40534-021-00253-y
Springer

Rail RCF damage quantification and comparison for different damage models

Visakh V. Krishna[1] · Saeed Hossein-Nia[1] · Carlos Casanueva[1] · Sebastian Stichel[1] · Gerald Trummer[2] · Klaus Six[2]

Does a more complex model always mean that it is more accurate?
→ model validation?

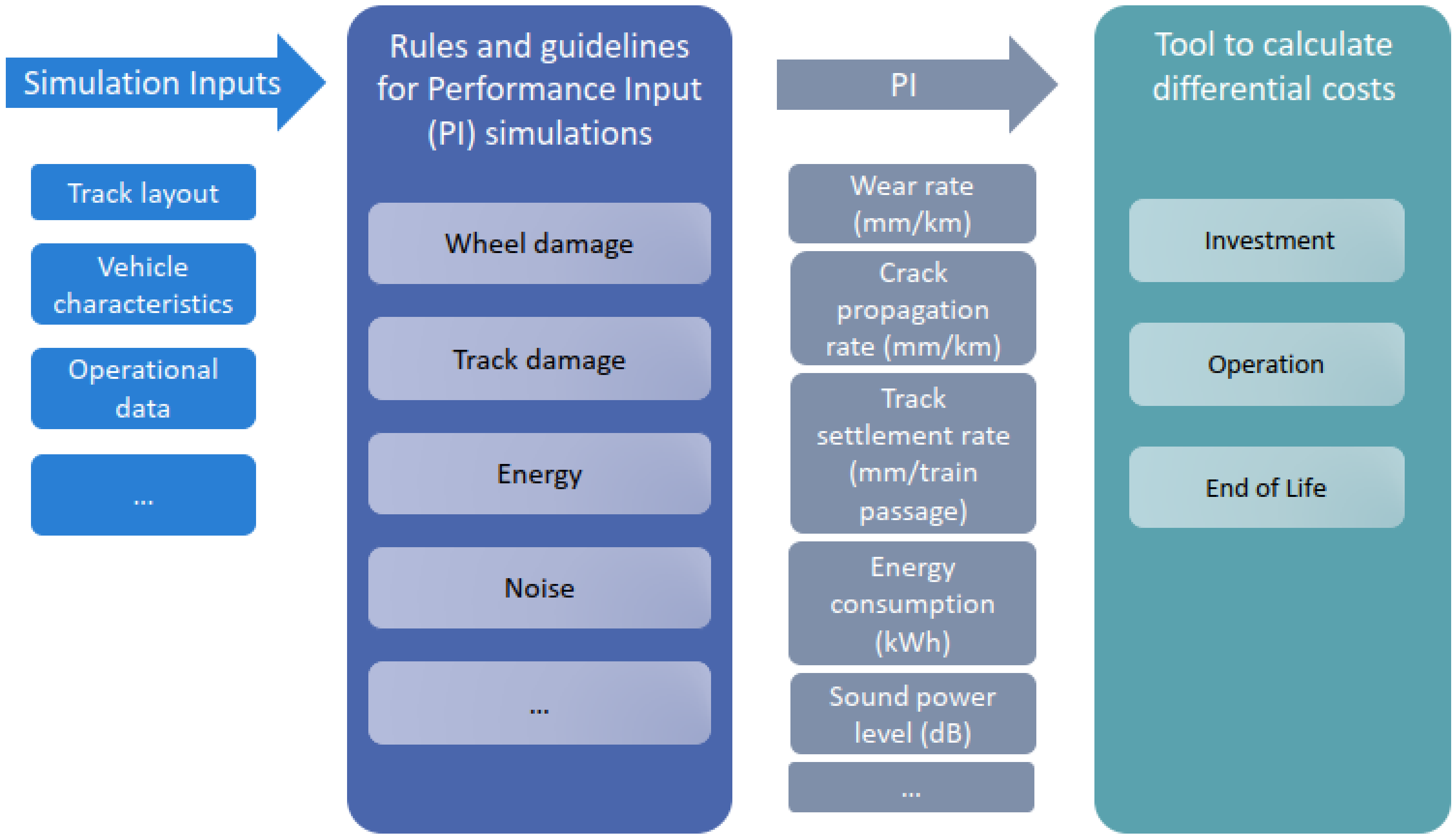
Universal cost model: gaps in track damage modelling

IAVSD'23 OTTAWA – ICRI WORKSHOP

CARLOS CASANUEVA

KTH ROYAL INSTITUTE OF TECHNOLOGY, STOCKHOLM, SWEDEN

What is the UCM



UCM tool modules – simulation tools

- Potential Hazards
- Energy
- Noise
- Vehicle Maintenance
- Rail Maintenance
- Ballast Maintenance
- End of life cost modelling

Simulation of Performance Inputs (PI) that generate a cost-trigger

e.g. “too much flange height” triggers a “wheel reprofiling” operation with a certain cost

Workshop discussion questions

Scenario and Operation → Dynamics → Differential settlement → Track quality → Ballast Tamping → Unit costs

Are there more efficient approaches?

How do other actors approach this cost estimation?

Are there other simulation possibilities?

Questions? Ideas? Opinions?

Discussion

UK track access charge model: methodology and impact on rolling stock

Prof Yann Bezin & Prof Adam Bevan

University of Huddersfield, United Kingdom

University of HUDDERSFIELD

Institute of Railway Research

Calculation and approval of VUC

Passenger vehicle e.g.

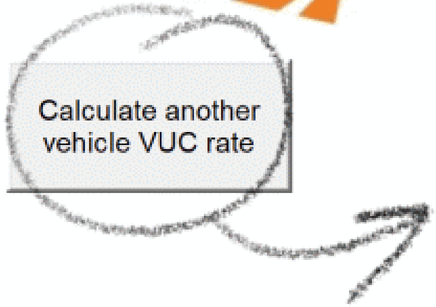
CP6 VUC Calculator: **Freight vehicles**

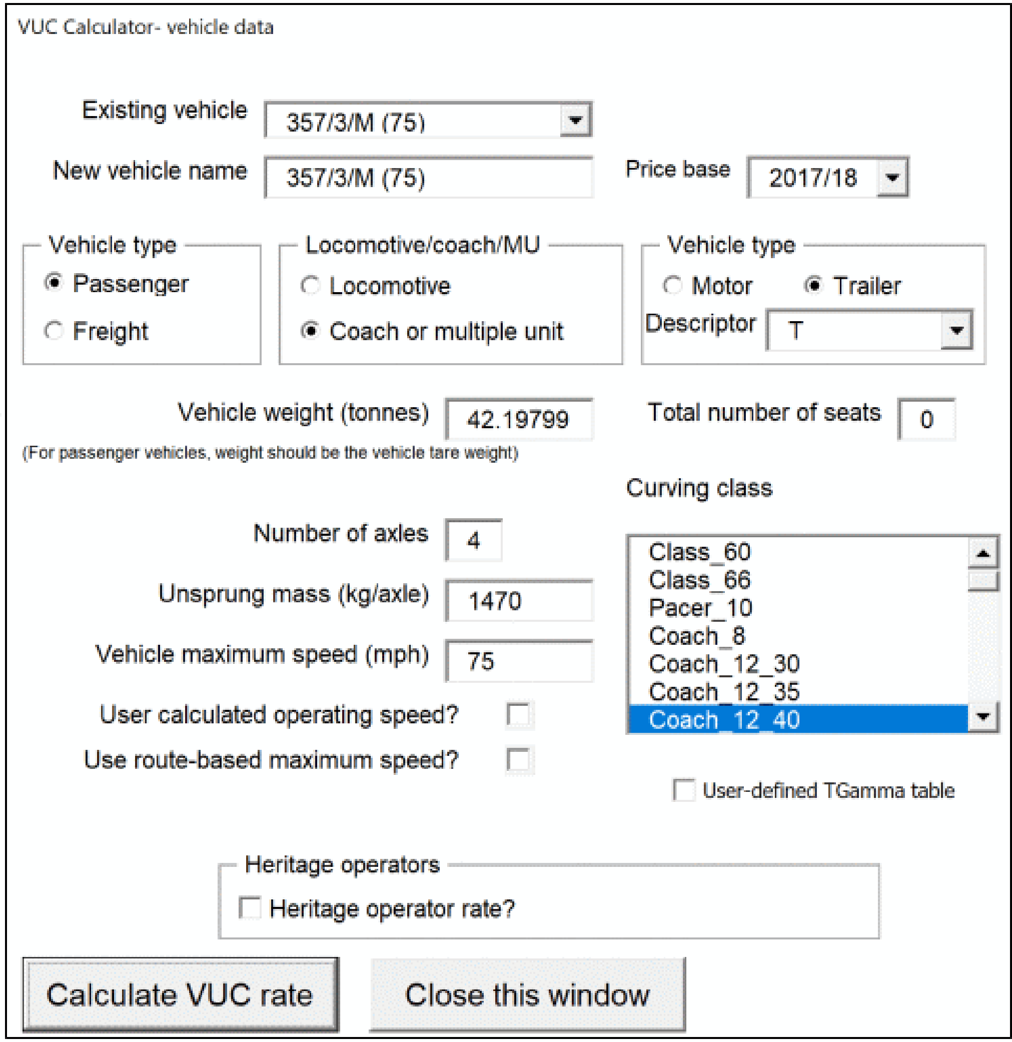
V7e: March 2019

NetworkRail

Vehicle data
Vehicle name/class
Load condition
Number of axles
Weight (t)
Unsprung mass (kg)
Curving class
Suspension band
RFC value?
Suspension factor
Ct factor (structures)

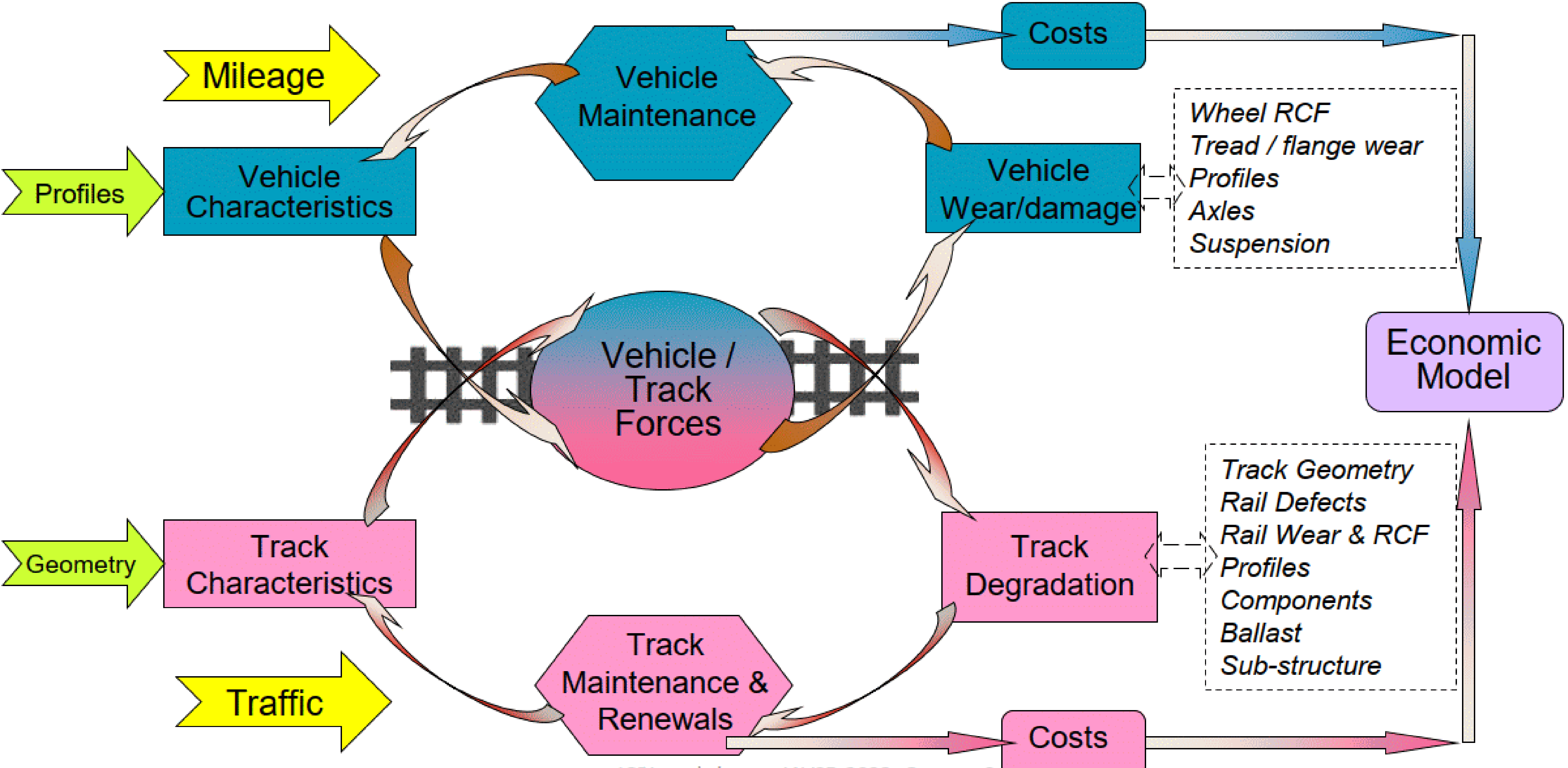
Calculated VUC						
All values in £/kGTM	**2017/18 prices**					
Existing CP5 rate?		**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**





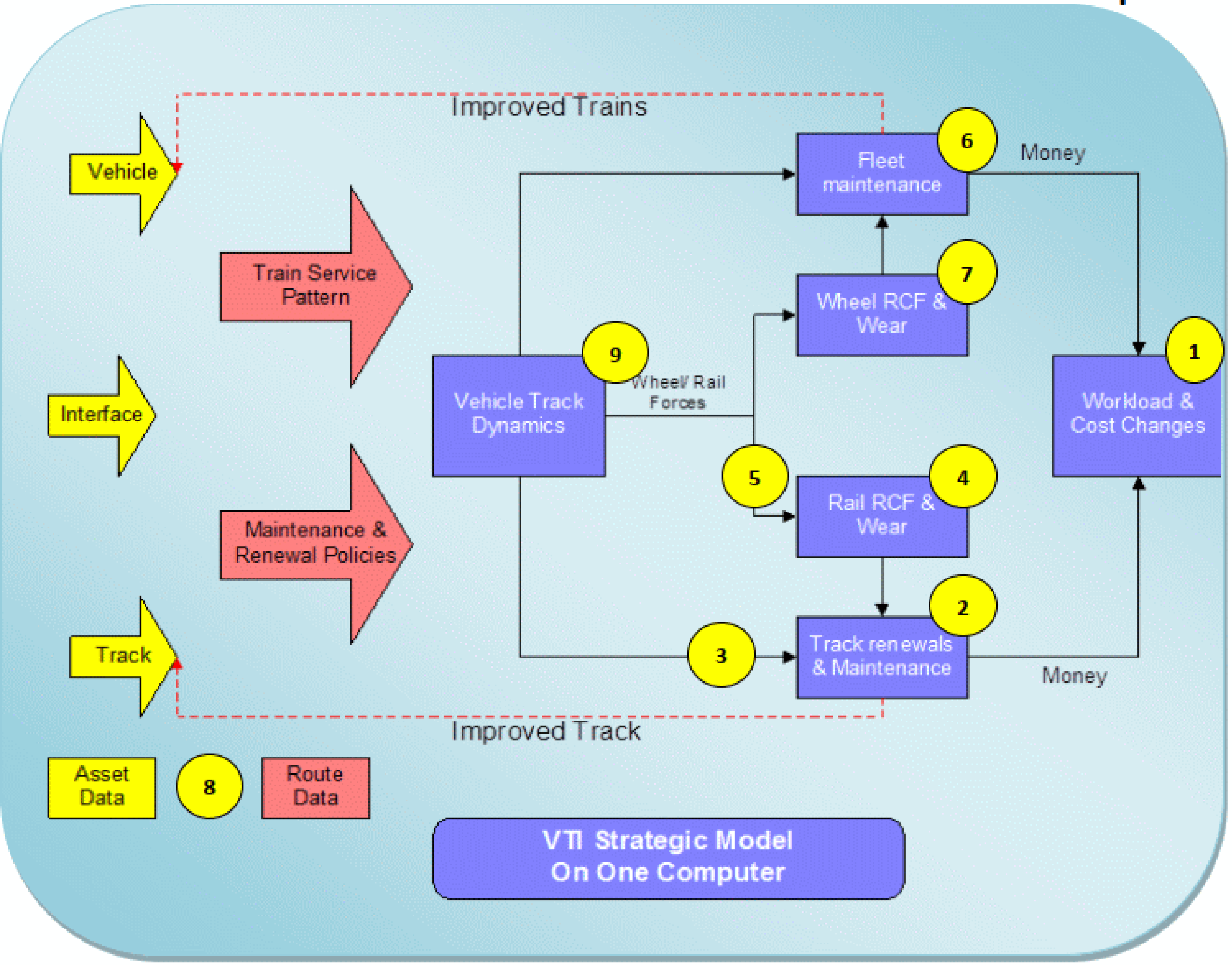
VTISM cost modelling framework (whole life / whole system)

Developed for RSSB, Network Rail and V/T SIC by Serco and University of Huddersfield



VTISM software modules

VTISM is a collection of integrated software modules, databases, simulation software and user defined renewal and maintenance policy criteria



Item	Associated Module(s)
1	VTISM Core Module
2	Track Strategic Planning Application (T-SPA)
3	Ride Force Calculator (RFC)
4	Whole Life Rail Model (WLRM)
5	WLRM Import Converter
6	Wheelset Management Model (WMM)
7	Wheel Profile Damage Model (WPDM)
8	VTISM data libraries / databases
9	Vehicle-track dynamics simulation software such as VAMPIRE® and SIMPACK® or other commercially available tool

Example applications

- Analyzing train design / configuration
  - Vehicle and RCF damage on different routes
  - Whole system (track ands wheelset) costs
- Impact of axle loads and train architecture on vertical deterioration and costs
  - 12-14% vertical damage cost saving for articulated train compared with conventional bogie arrangement.

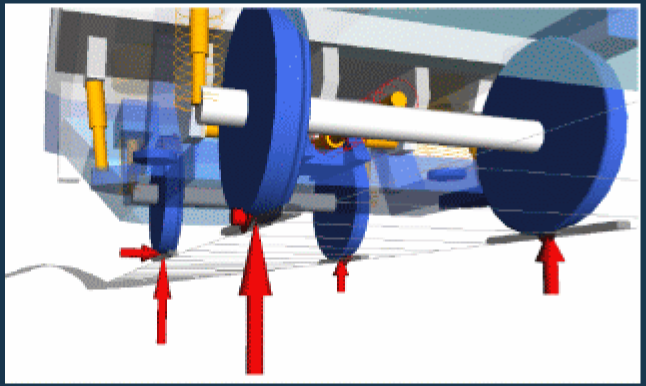
Discussion

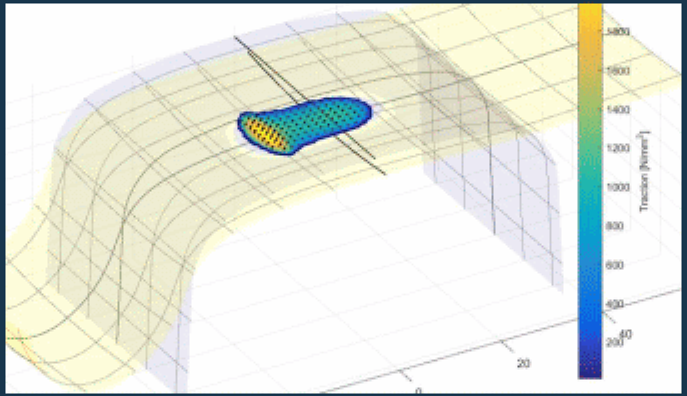
Session 4

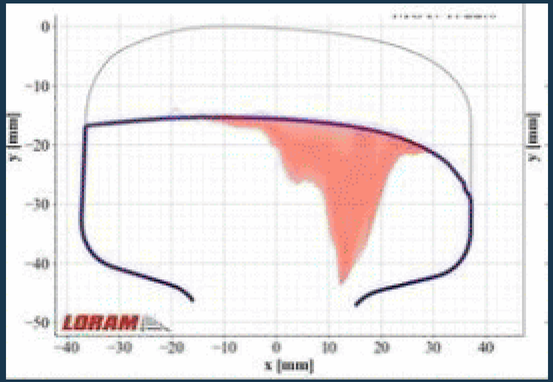
August 24th, 2023

Wheel-rail contact simulation with measured profiles

Edwin Vollebregt



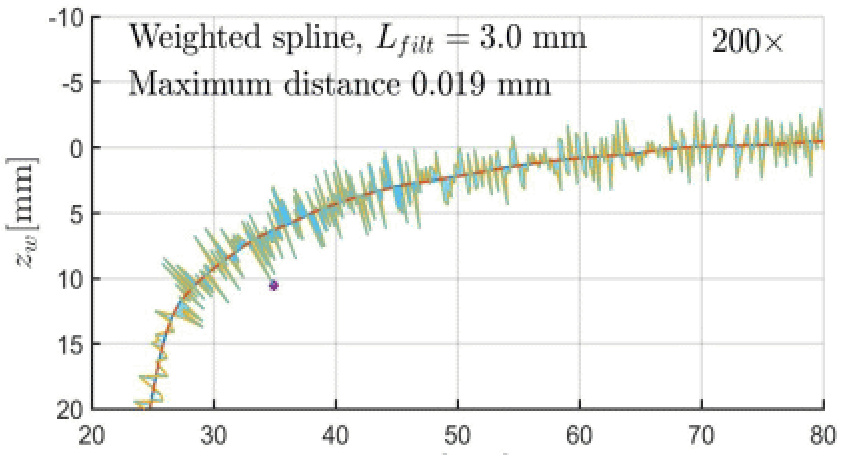


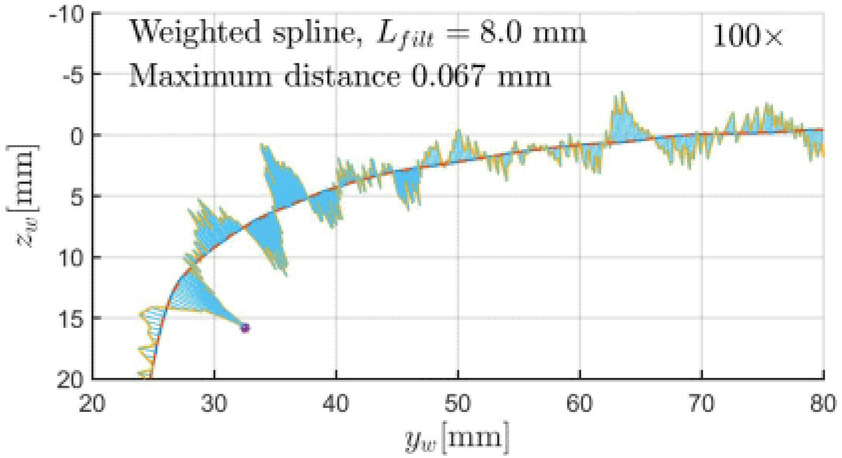


Smoothing of measured data

- Measurement noise, limited accuracy data
- True variability of actual profile

```
-32.240000  -0.785494
-32.220000  -0.784154
-32.200000  -0.782814
-32.180000  -0.781474
-32.160000  -0.780134
-32.0  -.769
-31.5  -.737
-31.0  -.705
-30.5  -.675
-30.0  -.646
-29.5  -.619
-29.0  -.592
```



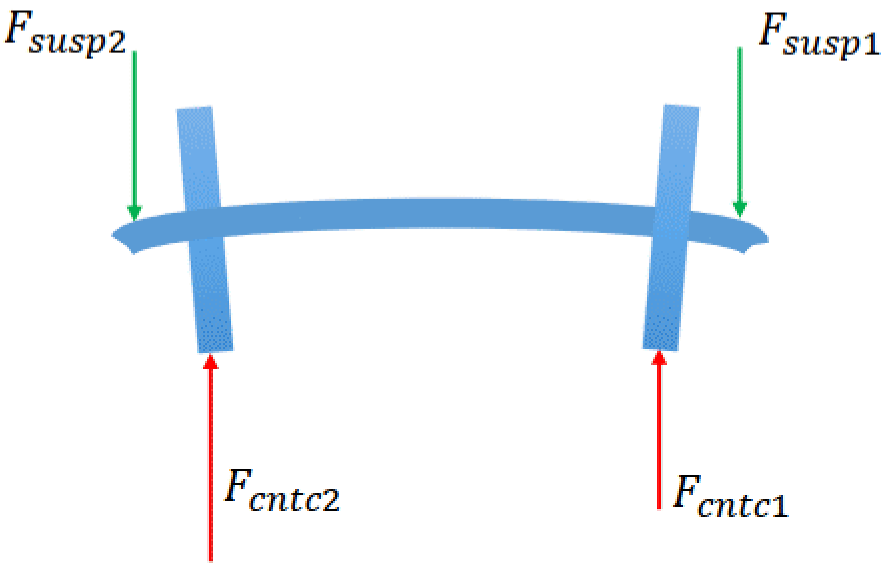


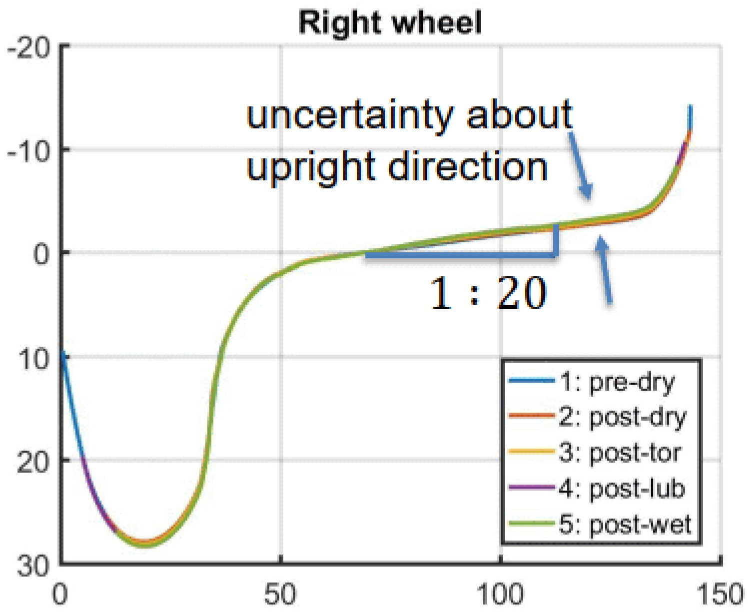
LORAM Technologies

Actual orientation

- What is the overall vertical direction?
- How do we accommodate rail roll and axle bending?

70-ton freight,
loaded: ± 3 mrad





Outlook

- Reject bad input data
- Conventions, alignment of measured profiles
- Cubic spline interpolation
- Spline filter L_{filt} - easy to understand, physical interpretation
- Investigate effects of axle bending and track deflection

Discussion

POLITECNICO
MILANO 1863

DEPARTMENT OF MECHANICAL ENGINEERING

ICRI 2023 Workshop at IAVSD

Simplified modelling approaches for non-Hertzian and conformal wheel/rail contacts

Binbin Liu

Department of Mechanical Engineering
Politecnico di Milano, Italy

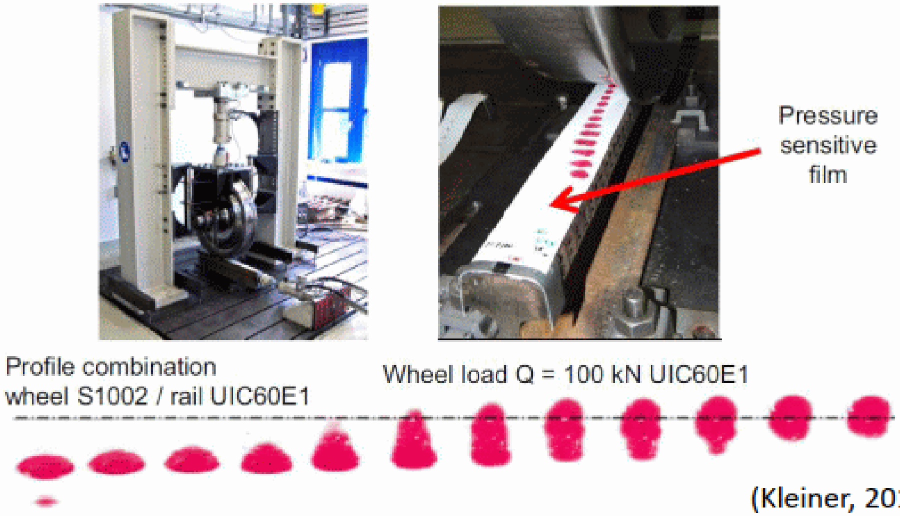
mecc

DIPARTIMENTO DI ECCELLENZA
MIUR 2018-2022

24th August 2023

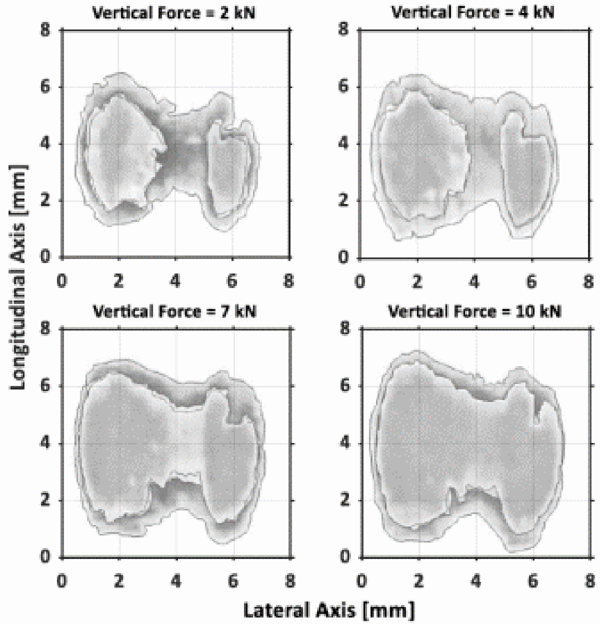
Wheel/rail contact in practice

- **Non-Hertzian**



(Kleiner, 2011)

Roller rig measurement



(Radmehr et al., 2020)

- **Conformal**

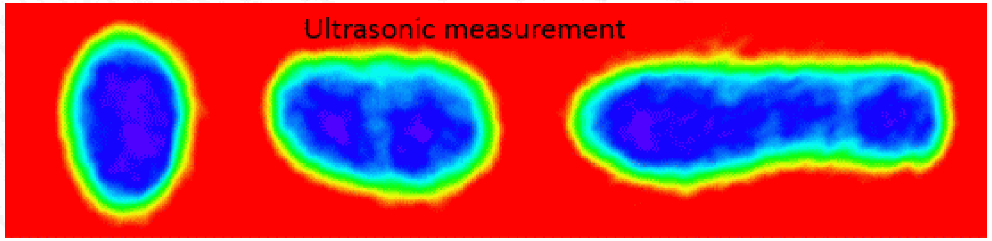
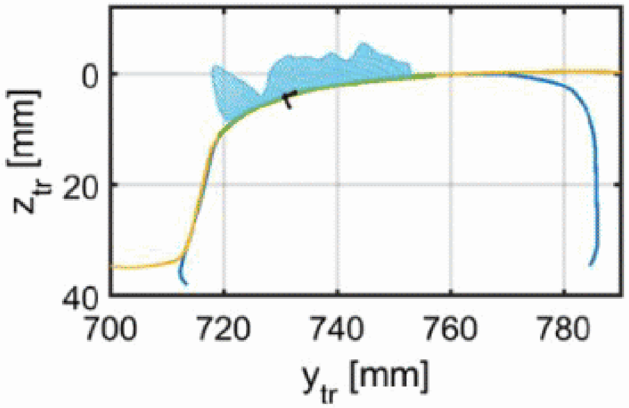


Fig.4 Evolution of the contact patch due to increasing conformity. From left to right, Hertzian (brand new elements), lightly conformal contact (low wear level), heavily conformal contact (highest wear).

(Pau et al, 2010)

Field measurement



(Vollebregt, 2020)

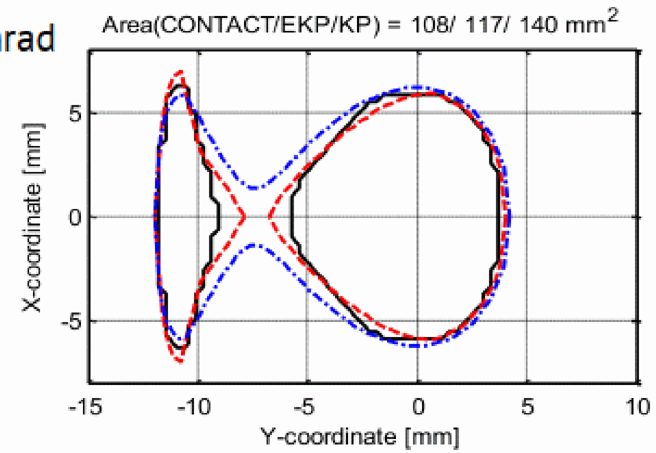
Extended Kik-Piotrowski model (EKP, Liu et al. 2016)

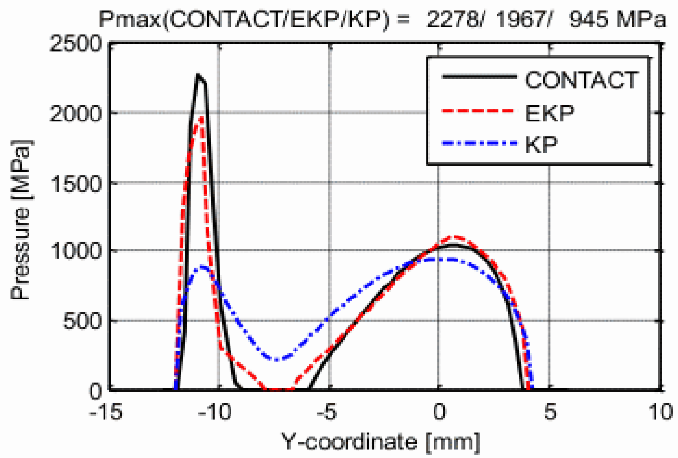
- fast
- approximate
- non-elliptic (non-Hertzian)

Improvements wrt KP model

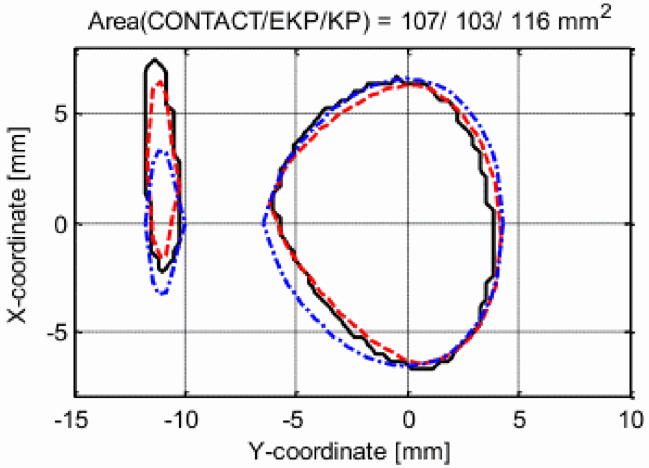
- contact patch shape and size
- pressure distribution
- effect of yaw angle (ϕ)

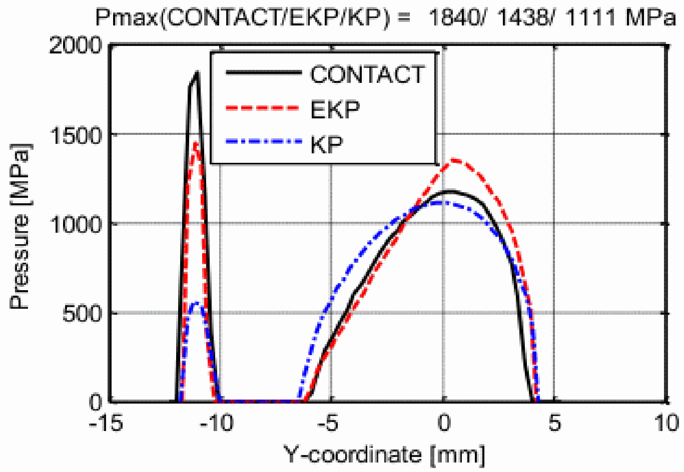
ϕ = 0 mrad





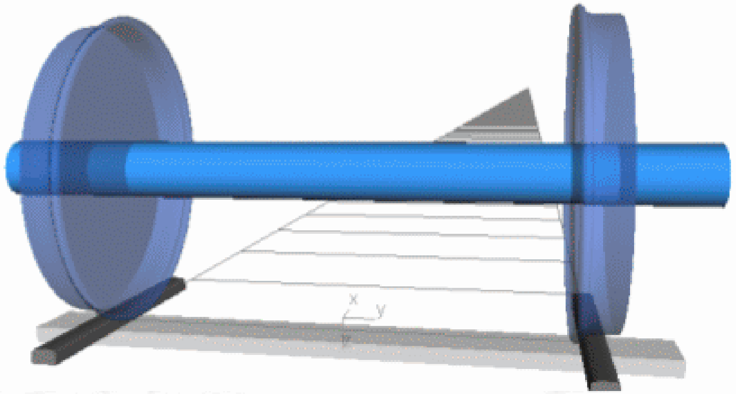
ϕ = 25 mrad





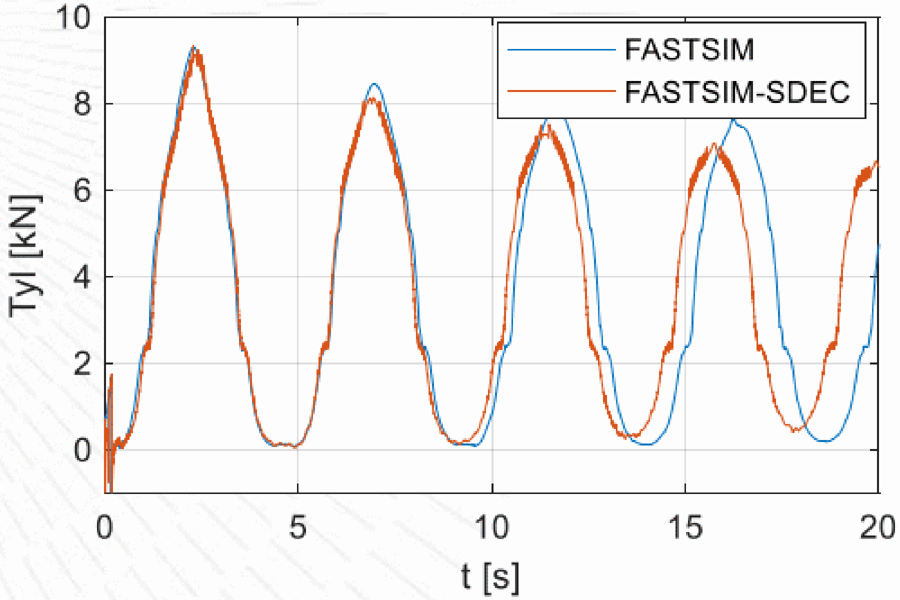
B. Liu, S. Bruni, and E. Vollebregt, "A non-Hertzian method for solving wheel–rail normal contact problem taking into account the effect of yaw," *Veh. Syst. Dyn.*, vol. 54, no. 9, pp. 1226–1246, 2016.

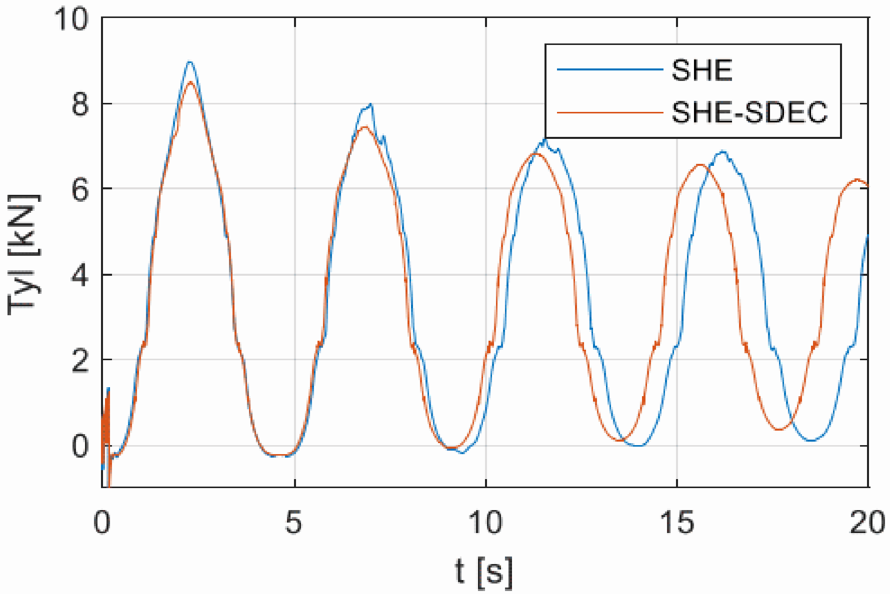
Hunting of a free wheelset



- Profile: S1002/UIC60
- Mass: 16000 kg
- Gauge: 1435 mm
- Cant: 1/40
- Speed: 2 m/s

Creep forces

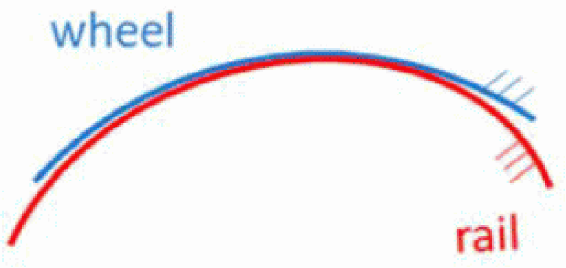




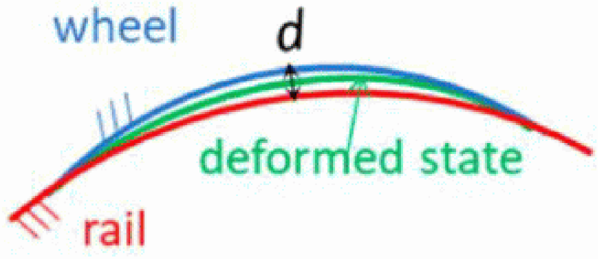
Binbin Liu, Bin Fu, Qinghua Guan, Stefano Bruni, Application of non-Hertzian creep force models in rail vehicle dynamics simulation, IAVSD 2023, Ottawa, Canada.

Conformal contact

- FEM
- BEM + ICs (FEM)
  - Li (2002)
  - extended CONTACT (Vollebregt et al., 2014)
- BEM + ICs (approximate)
  - CONFORM (Paul et al., 1981)
  - Blanco-Lorenzo et al. (2016)
- **Simplified approaches**
  - Kik-Piotrowski + FASTSIM (1999)
  - STRIPES + FASTSIM (Quost et al. 2006)
  - extension of Kik-Piotrowski + FASTSIM (Boccini et al., 2016)
  - Multi-Hertzian + FASTSIM (Pascal et al., 2016)
  - **Strip-wise Kik-Piotrowski (Marques, Magalhães, Liu et al., 2018)**
  - extension of Kik-Piotrowski(ICs) + FASTSIM (Nencioni et al., 2022)
  - **Modified INFCON + FaStrip (Chen, Liu, An, Wang and Bruni, 2023)**



Explicit conformal



Implicit conformal

Binbin Liu, Edwin Vollebregt & Stefano Bruni (2023) Review of conformal wheel/rail contact modelling approaches: towards the application in rail vehicle dynamics simulation, Vehicle System Dynamics, DOI: 10.1080/00423114.2023.2228438

Conclusions: remarks

- Although the Hertzian wheel/rail contact model is still used in MBS simulations, simplified non-Hertzian models are available to be used in the context of MBS simulation which is the choice of future applications.
- Only a **few** non-Hertzian creep force models are capable to be used in the context of MBS simulations.
- No established model for the evaluation of contact forces/stresses in a conformal situation in the context of rail vehicle dynamics simulations which requires further research.
- Varied simplified non-Hertzian and conformal contact models are available, but a **benchmark** to assess their performance at the system level is still missing.

Discussion

Simulation and measurement of profile evaluation

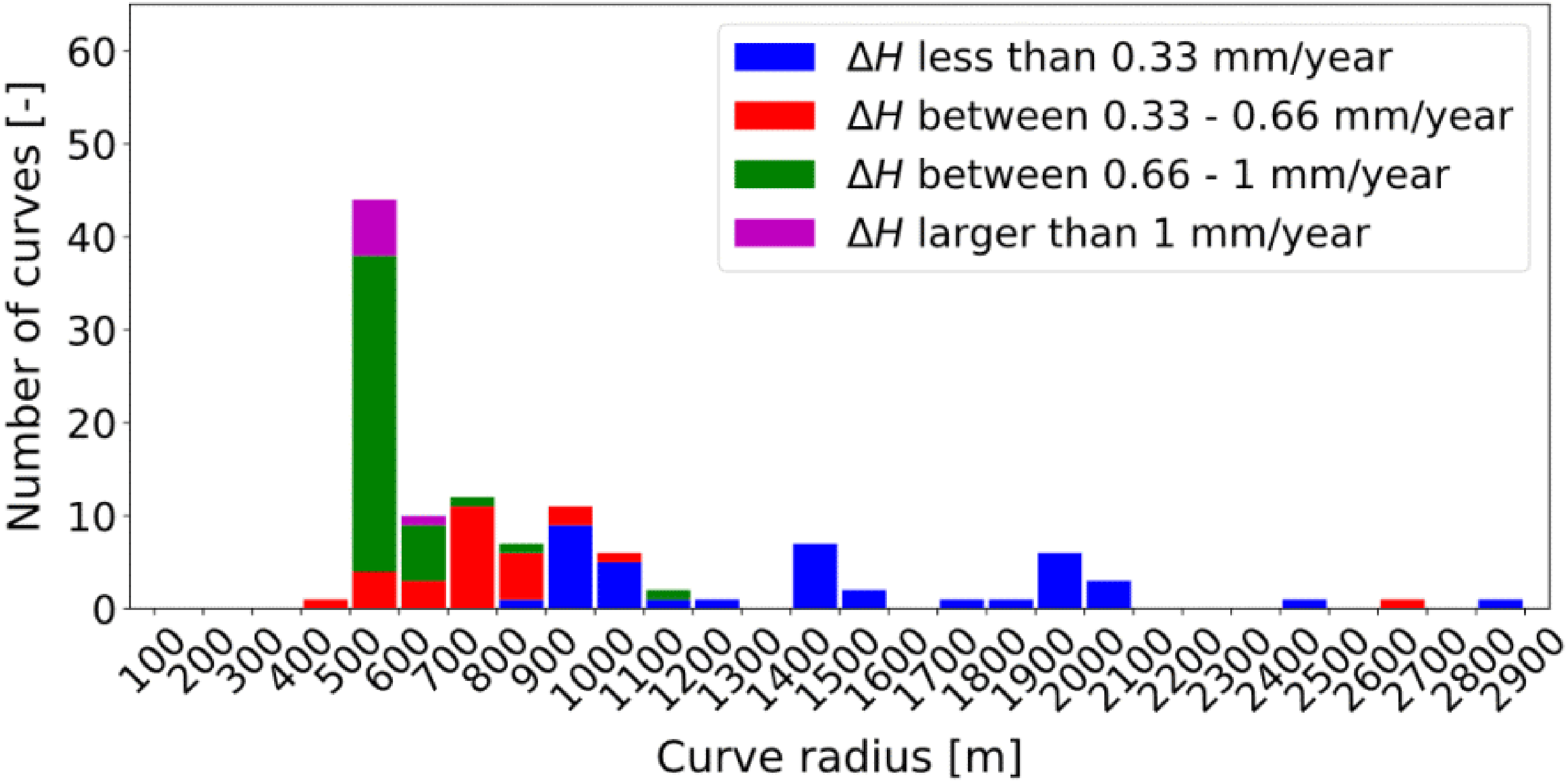
Sebastian Stichel, *Saeed H-Nia, Visakh V. Krishna, Kristofer Odolinski, Peter T. Torstensson, Abderrahman Ait-Ali, Lars Sundholm, Per-Olof Larsson Kråik*

ICRI Workshop, Ottawa, 2023-08-24

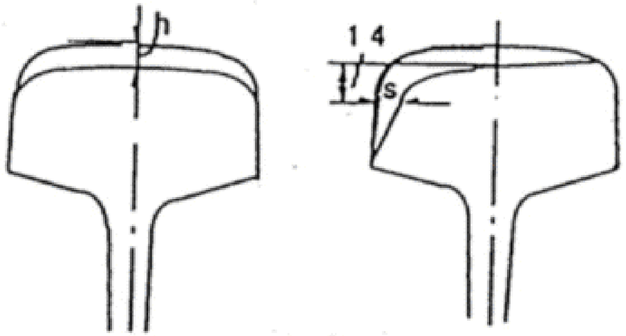
Maintenance planning

- The rail life on sharp curves on the Iron ore line is approximately a quarter of that on tangent track

Growth of H-index during period 2014-2019



$$H = h + \frac{s}{2}$$

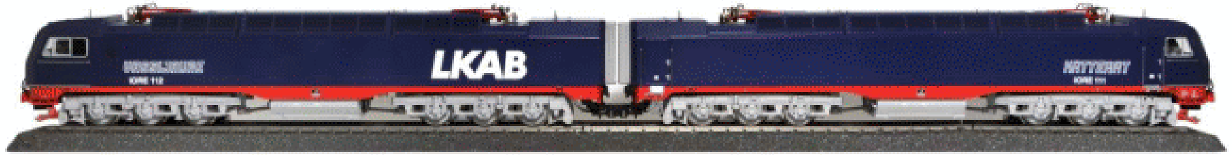


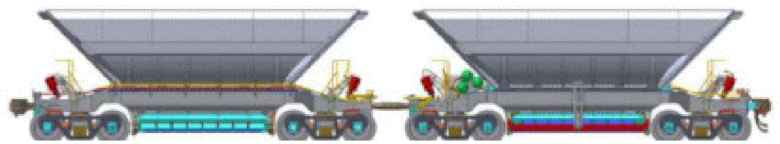
Case study

- Rails mounted by Pandrol E+ fasteners to monobloc sleepers
- Curve radius 495 m and cant 60 cm
- Gauge width at start of simulation 1440 mm. Gauge widening 1.5 mm per year

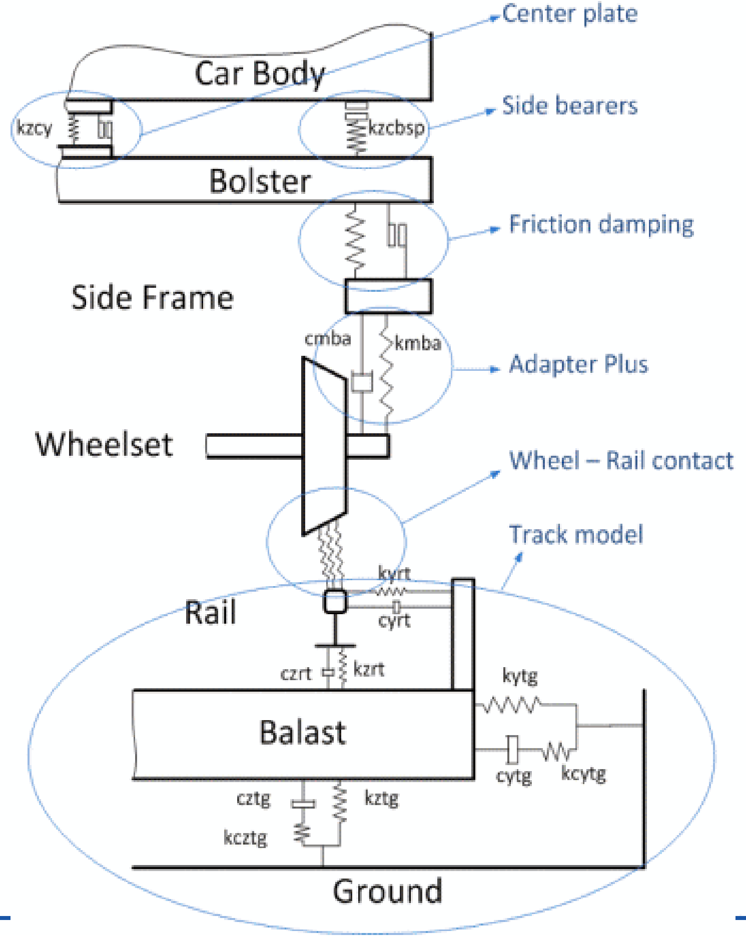
- **Comparison of two different rail grinding strategies:**
  - ➢ **Rail grinding twice a year with rail material R350LHT**
  - ➢ **Annual rail grinding with rail material R400HT**

Simulation models



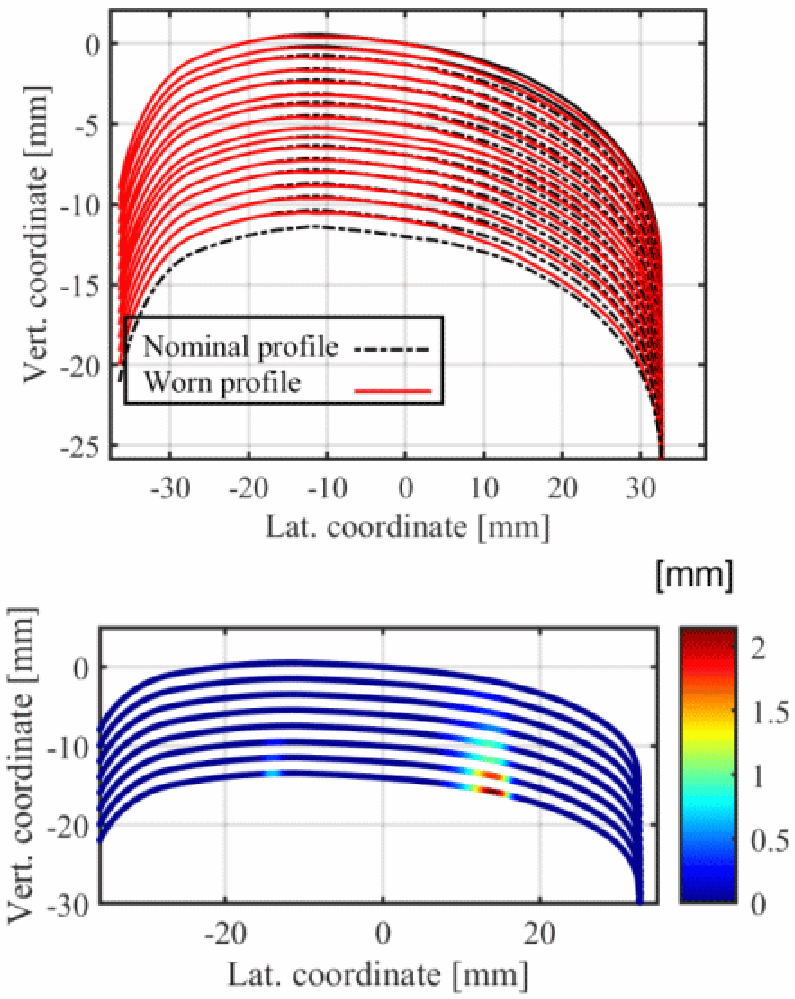


- MBS model of wagon with three-piece bogies is built in GENSYS.
- The model is validated against measurements.
- The locomotive MBS model is provided by Bombardier/Alstom in SIMPACK and translated to GENSYS.

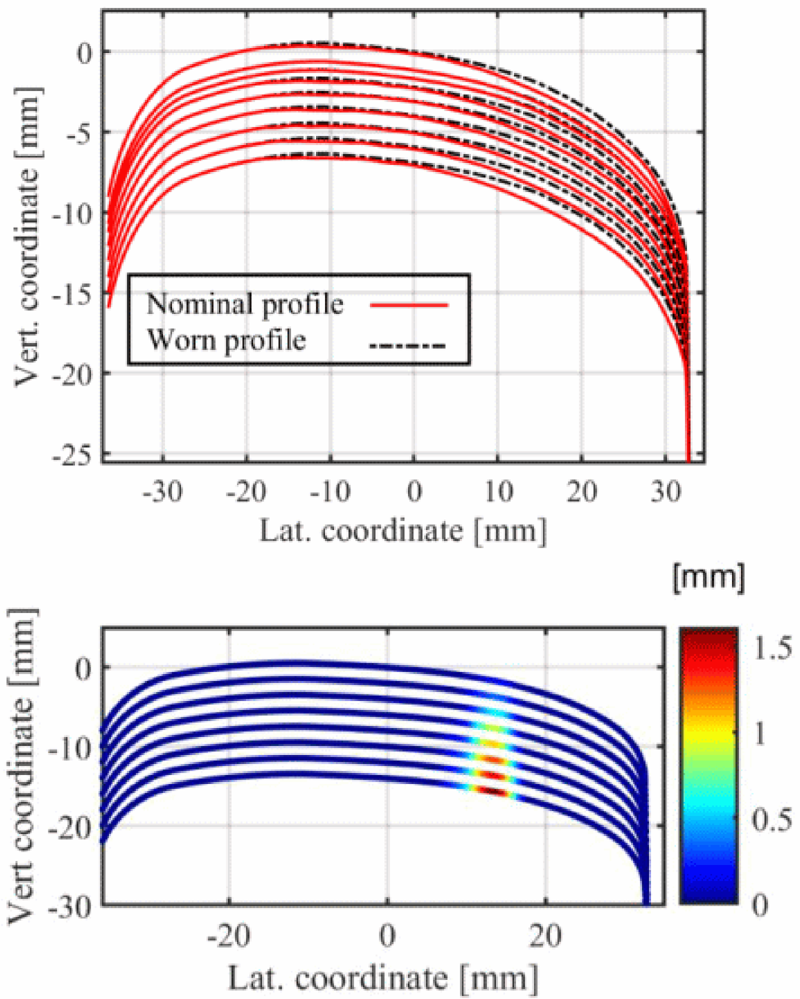


Comparison of Maintenance strategies

R350LHT



R400HT



High rail

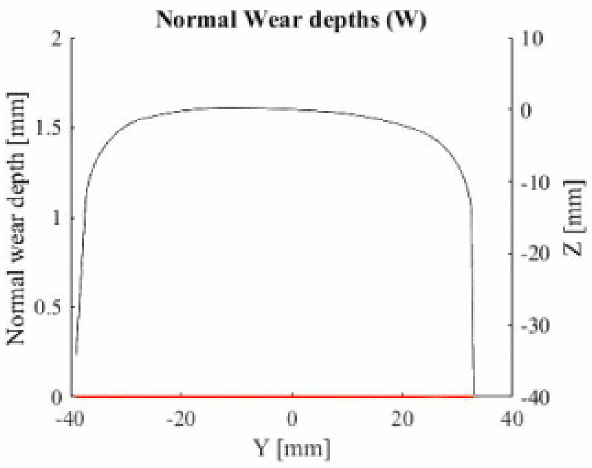
04DEC23 asked Saeed to explain

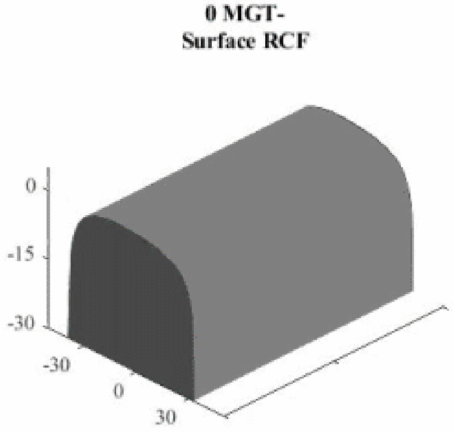
Rail surface damage evolution

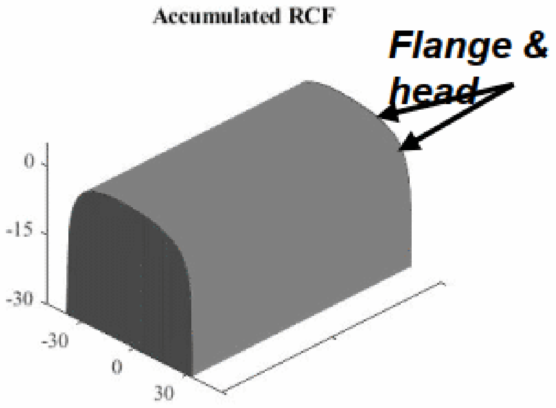
Standard Y25 bogie

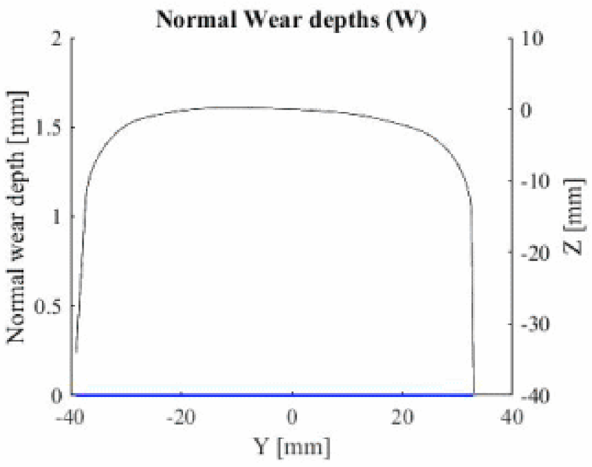
R = 450 m
Outer rail
100 MGT
~4 years

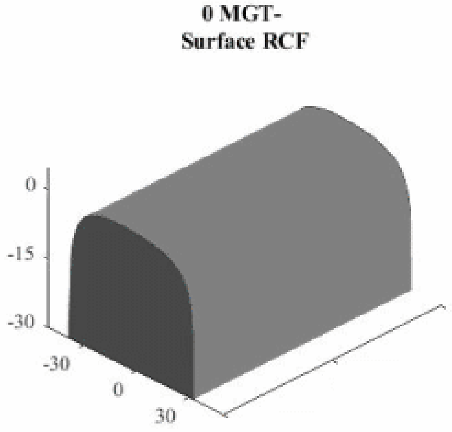
FR8RAIL bogie

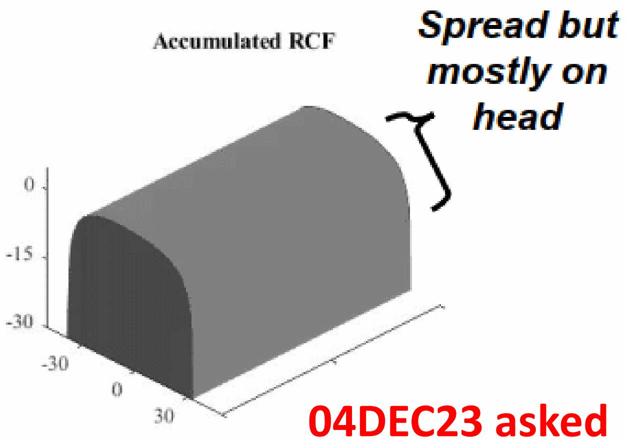










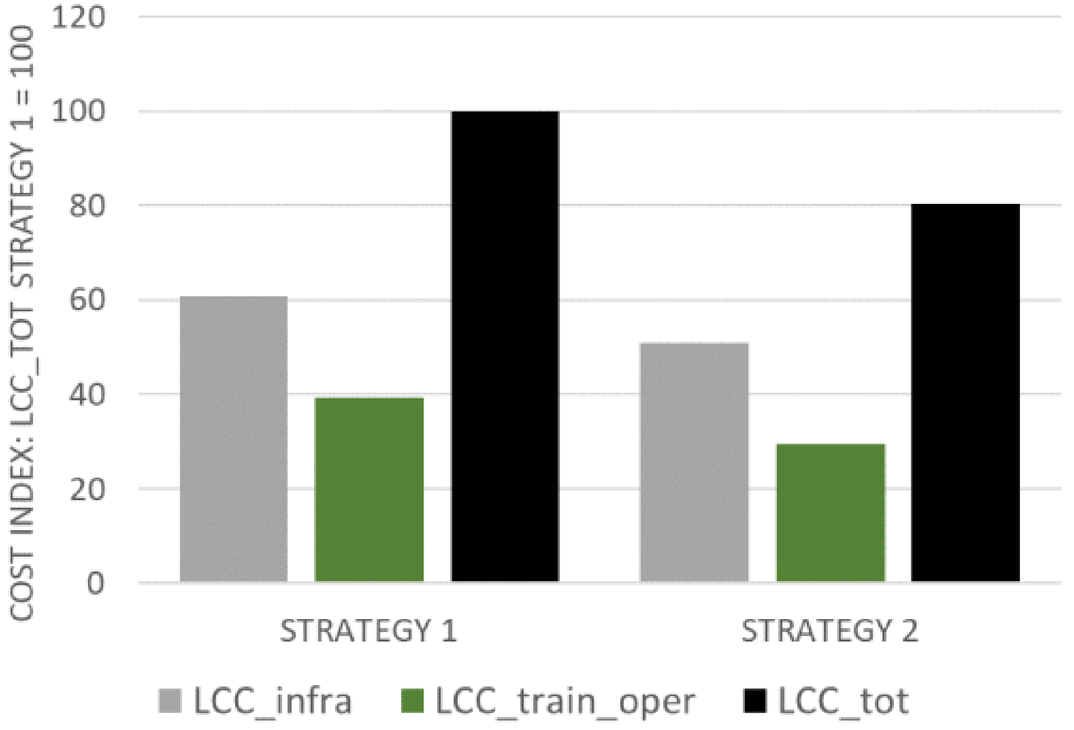


04DEC23 asked Saeed to explain

Wear depth | Surface RCF | Accumulated RCF

LCC results

- Harder rail material (R400HT) and grinding once per year (“Strategy 2”) better than softer rail material (R350LHT) and grinding twice per year (“Strategy 1”)
- **Note**
  - Neither strategy in this case study generates costs linked to rail failures and no impact on rail renewal frequency.
  - Noise costs assumed to be zero but relevant in other case studies with railway line in populated areas



Discussion

ICRI workshop Ottawa
August 24, 2023

ICRI Contact Benchmark

Edwin Vollebregt, Saeed Hossein-Nia, Binbin Liu

Why hold a contact benchmark?

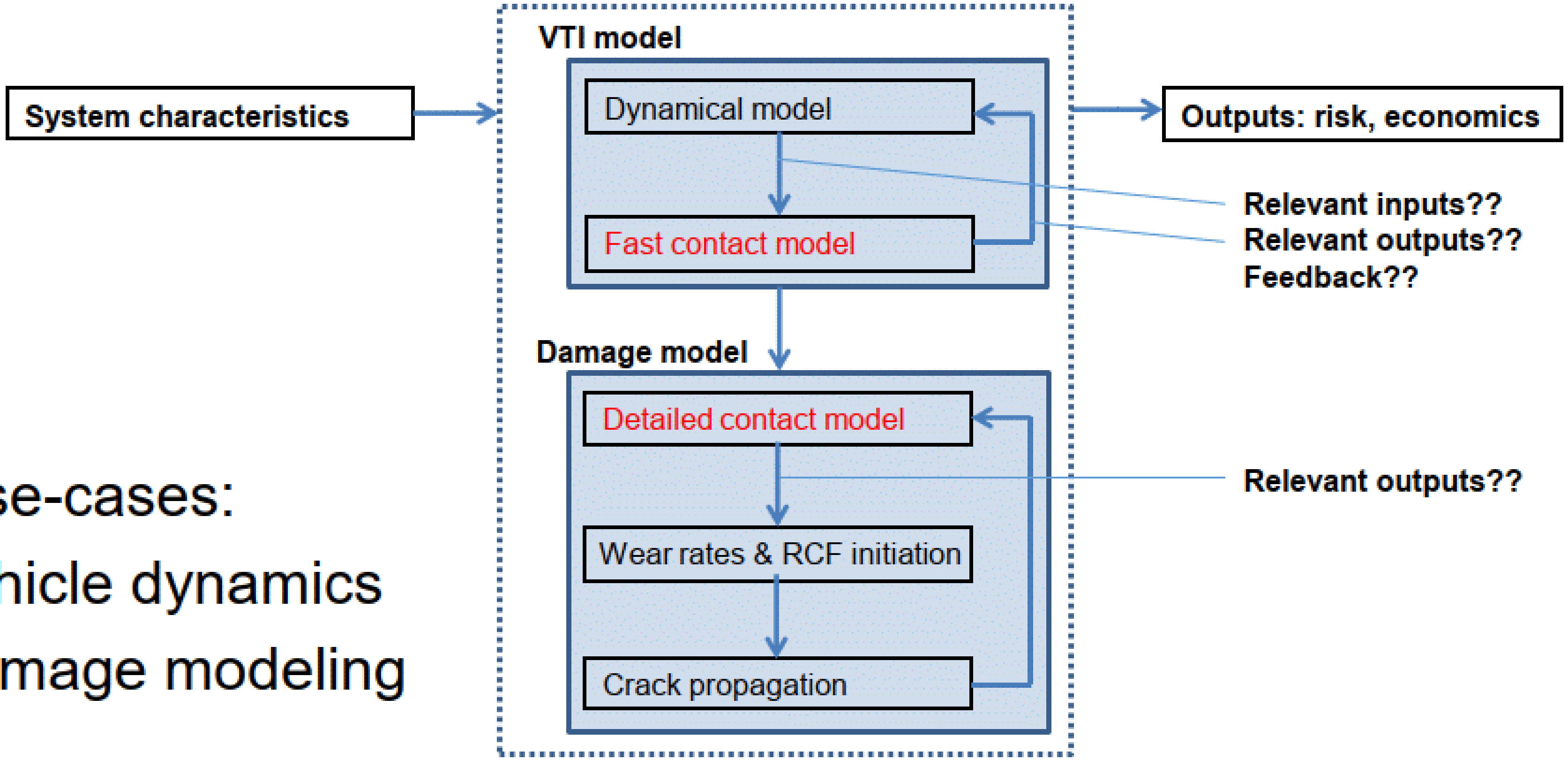
Many papers on fast (approximate) non-Hertzian methods

- Demonstrated on just a few, isolated cases
- Little comparison between different methods
- Ignoring the context of the application

→ How do these methods perform in application scenarios?
→ What are the pros and cons of different methods?

Advance the state of the art for wheel-rail contact evaluation

How to evaluate contact methods



Two use-cases:

1. Vehicle dynamics
2. Damage modeling

Proposed schedule

1. Initial inputs, Matlab model: September 2023
   – participants examine test set-up, report findings
   – organizers respond to questions, refine test set-up
2. On-line meeting: January 2024?
   – finalize test set-up, scope, time-line
   – participants run test-cases, organizers collect results
3. Workshop: Istanbul, May 2024?
   – discuss outcomes, discuss reporting
4. Special issue: VSD, submitting by December 2024?

Discussion