Tampere University

Research Centre TERRA Geo Road Rail

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–
Track-friendliness of freight wagons on the Finnish Rail Network

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Track-friendliness

A track-friendly bogie:

~ *produces low/moderate forces on the track*;

~ *produces low abrasive wear or rolling contact fatigue on the track*;

~ *should be able to run on a 'non-perfect' track* (i.e., with significant track irregularities);

Such a bogie will cause *minimal track deterioration*; incur *less maintenance* and renewal activities; *reduce the costs* associated to it; and result in *favorable operating vehicle conditions*……

The Project!

- Supported by the **Finnish Transport Infrastructure Agency**.
- The aim of the project is to answer the question:

How can the track-friendliness of different freight wagons be evaluated?

- This study will focus on understanding the **'dynamic behaviour'** of the freight wagon fleet running in Finland.
- This study is the first part of a larger project, where in time the project develops different **assessment methods** and also a **framework**.

How to answer the question?

- **Phase 1**: To understand the loading behaviour of the freight gear.

An extensive review is carried out to study the design differences of the equipment; effect of the sprung and unsprung masses; role of primary and secondary suspension; clearances in the lateral, longitudinal and vertical direction; the steering ability in curved sections……

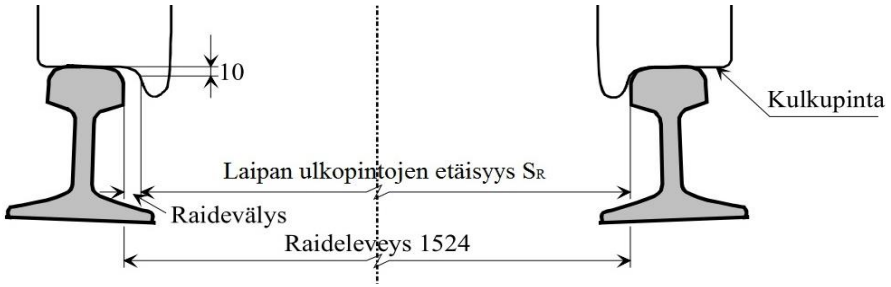
- Phase 2: Determining how the track-friendliness of different bogies could be estimated.

Key elements like forces, energy functions, wear rates, derailment coefficient, accelerations are identified that govern the track-friendliness of bogies. This phase works coherently with Phase 3. Ways to determine the costs incurred for the use of running gear (track access charge) on the network are also being evaluated.

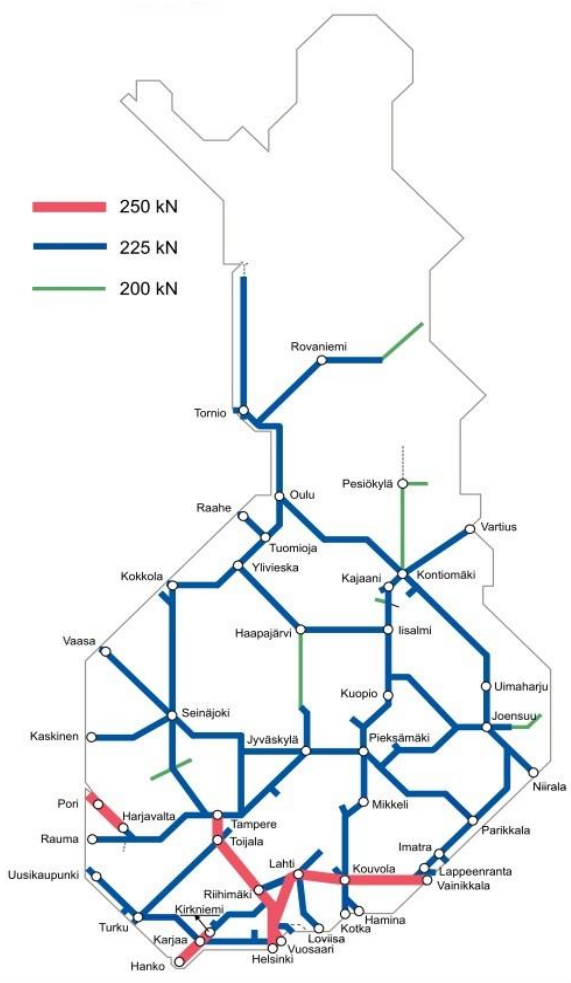
- Phase 3: Multi body simulation of freight wagons to understand the dynamic behaviour.

MBS sheds light on the dynamic loading of the wagons providing insights on the train-track interaction and lays the foundation for rail surface damage calculations. Such simulations give the liberty of analyzing a wide range of running conditions that are difficult to conduct on track.

The Finnish Rail Network



- Finland has nearly **6000 kilometers** of railways in use.
- The Finnish rail network has a track gauge of **1524 mm** with **60E1/54E1** rail profiles (with **1:40** inclination).
- For most of the rail network, the authorized axle weight is **22.5 tonnes**.
- In certain parts of the rail network, an axle weight of **25 tonnes** is also permitted. The speed limit for freight trains is upto **120 km/h**.



Freight Bogies running on the network:

Two-axle wagon

K16 (G type bogie)

K14 (G type bogie)

K17 bogie

Three-piece bogie

Y25 bogie

Phase 1: Evidence from literature

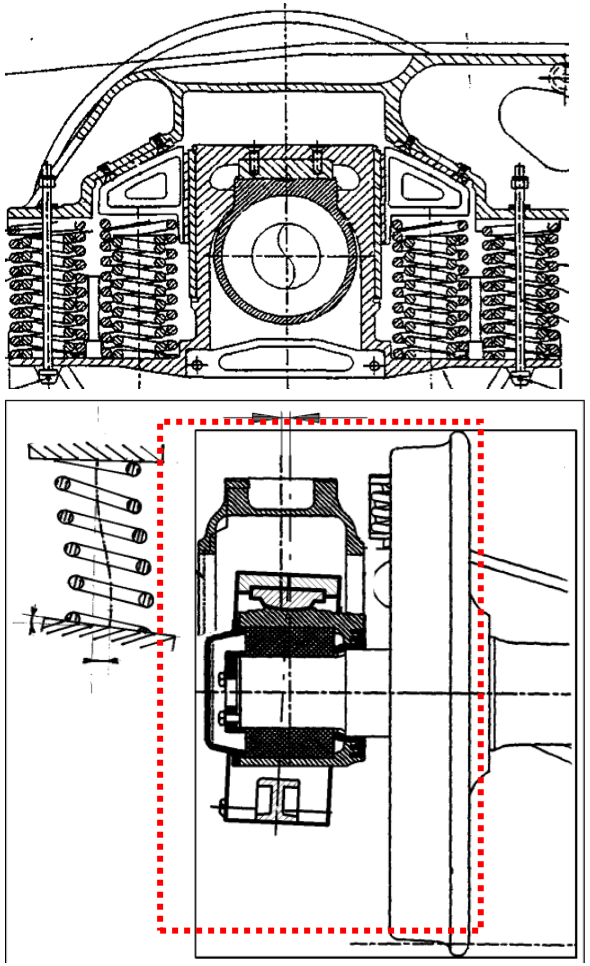
Effect of Freight Wagons on the rail network

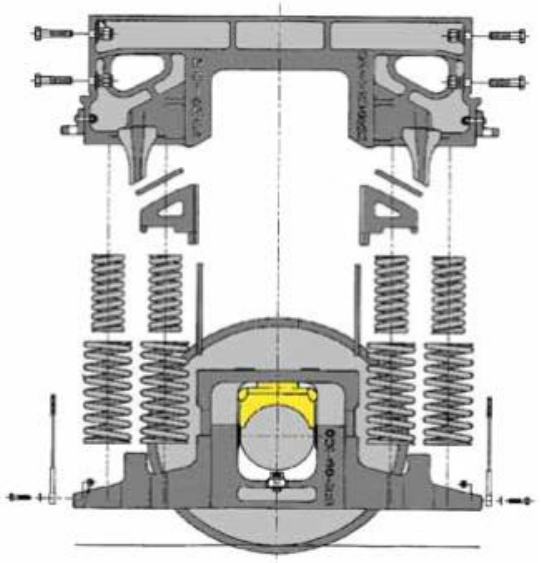
- **Interesting findings based on literature….**

  - **Soft suspension** Axle Motion bogies.
  - The **Stiff Y25 bogie** with a rigid bogie frame mounted with primary suspension and linkage damping prone to lock-ups.
  - The **three-piece bogie** with its unsprung mass and dependency on warp stiffness for improved running.

K17 Bogie

- Axle Motion Bogies designed to meet the 25-tonne axle load requirement in Finland.
- The seating arrangement of the saddle onto the wheelsets impose some **degrees of freedom, laterally**.
- The amount of lateral play is dependent on by the bending stiffness and axial stiffness of the springs.
- Lateral play is about **20-22.5 mm** and **9-9.5 mm** in the longitudinal direction.

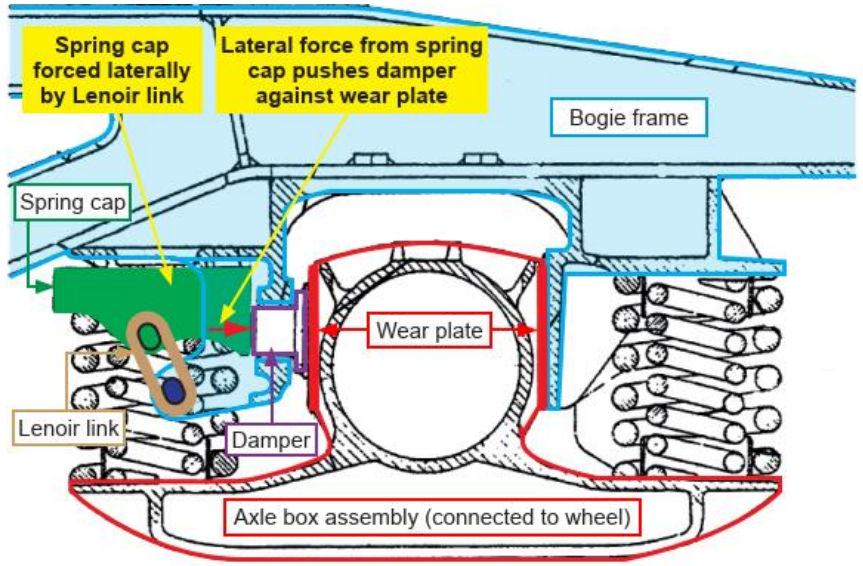


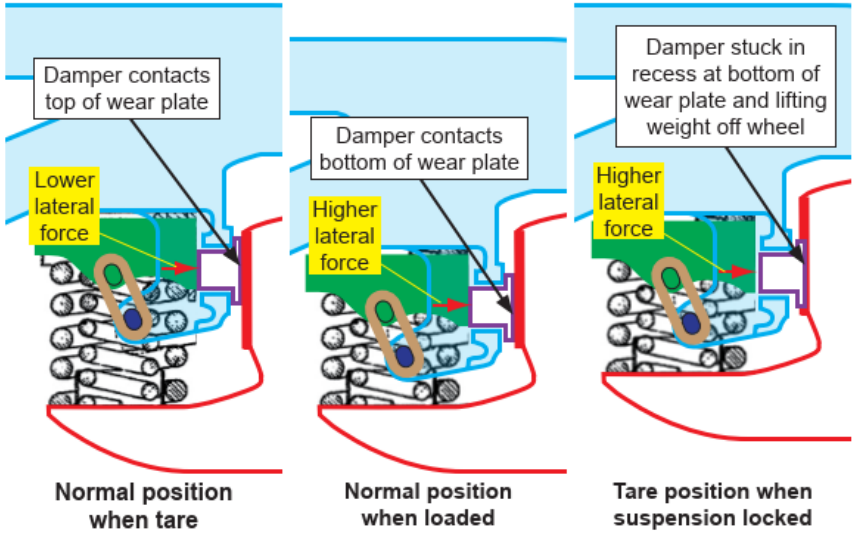


Ref: Bohumil Volf & Jan Ondrouch

Y25 Bogie:

- **Outer spring Tare conditions** and **Inner spring Laden conditions**, making the suspension of the vehicle **stiffer**.
- Part of the vertical force is applied via **'Lenoir' link** causing the spring cap to push a damper onto a wear plate on the axle-box.
- The frictional damping is load dependent.
- Some form of damping is provided by the action of side bearers and the central pivot joint.
- Lateral play is about **10 mm** (half of Axle motion bogie) and **4 mm** in the longitudinal direction.





Three-piece bogie:

- Two separate **side frames that rest directly on the axle boxes through adaptors** that allow only rotational freedom.
- Damping is provided by the **wedge friction dampers** working in vertical and lateral directions.
- Important parameter that influence curving is the total **longitudinal clearance between the axle box and the side frame**.
- Satisfactory curving in the three-piece 18-100 bogie, the clearance should compose **at least 8 mm**. maximum at 15-20 mm

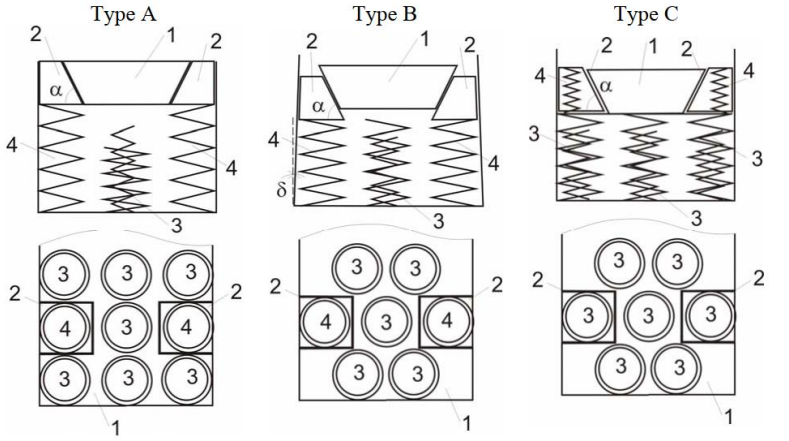
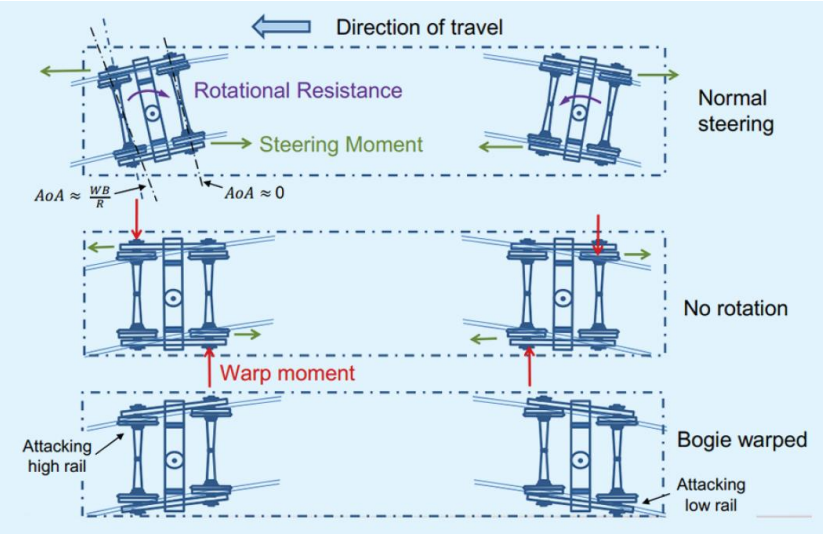


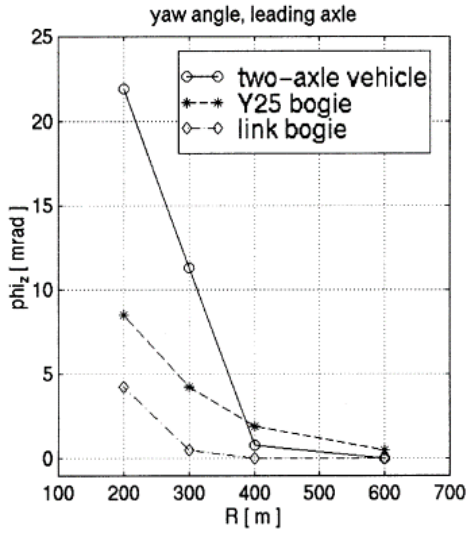
Fig. 1 Designs of central suspension shown in zero gravity condition: 1 – bolster, 2 – wedge, 3 – load springs, 4 – wedge springs

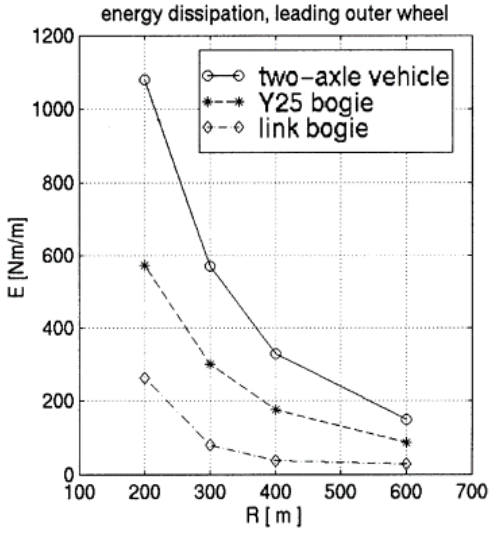


Ref: Orlova A; Boronenko Yu.

Test results from literature:

Curving performance is poor for the Y25 bogie!





Wheelset 1	Curve		Yaw angles vrs. Track ref. frame[mrad]		
Load Condition	Radius	Curvature (Ψ_0)	Steady-state(Ψ)	Peak	Ψ/Ψ_0
	[m]	[mrad]	[mrad]	[mrad]	[%]
Laden	200	5	4.1	4.1	82 %
Laden	400	2.5	0.9	1.4	36 %
Laden	1000	1	0.3	0.7	30 %
Tare	200	5	4.9	4.9	98 %

Table 14: Level III curving simulation - Wheelset Yaw angle.

LOAD	Curve radius	Speed	ANC	Y/Q
	[m]	[m/s]	[m/s^2]	[/]
Tare	200	7.5	0.6	0.15
Tare	100	11	0.6	0.20
Tare	60	6	0.6	0.43
Laden	60	6	0.6	0.13

Table 12: Maximum Y/Q value obtained with the Level 1 contact model.

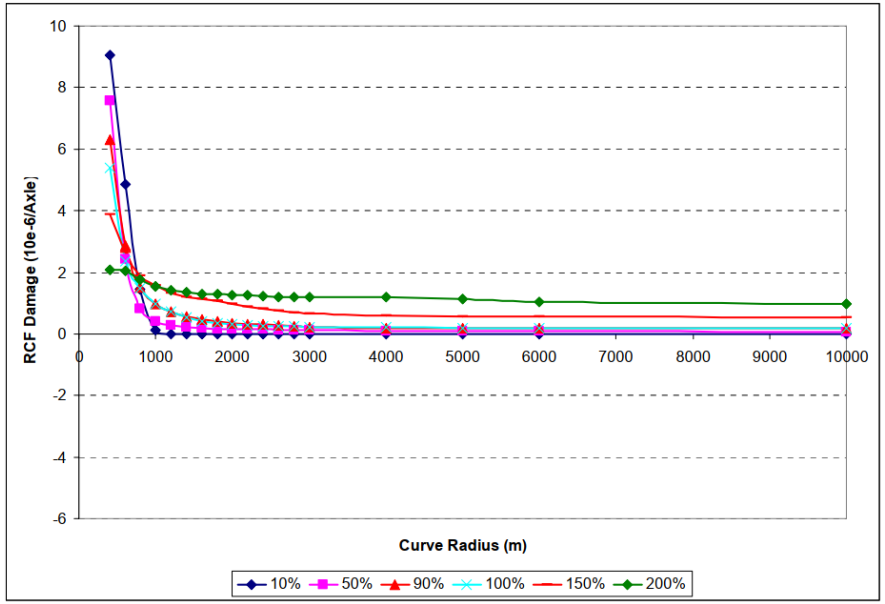
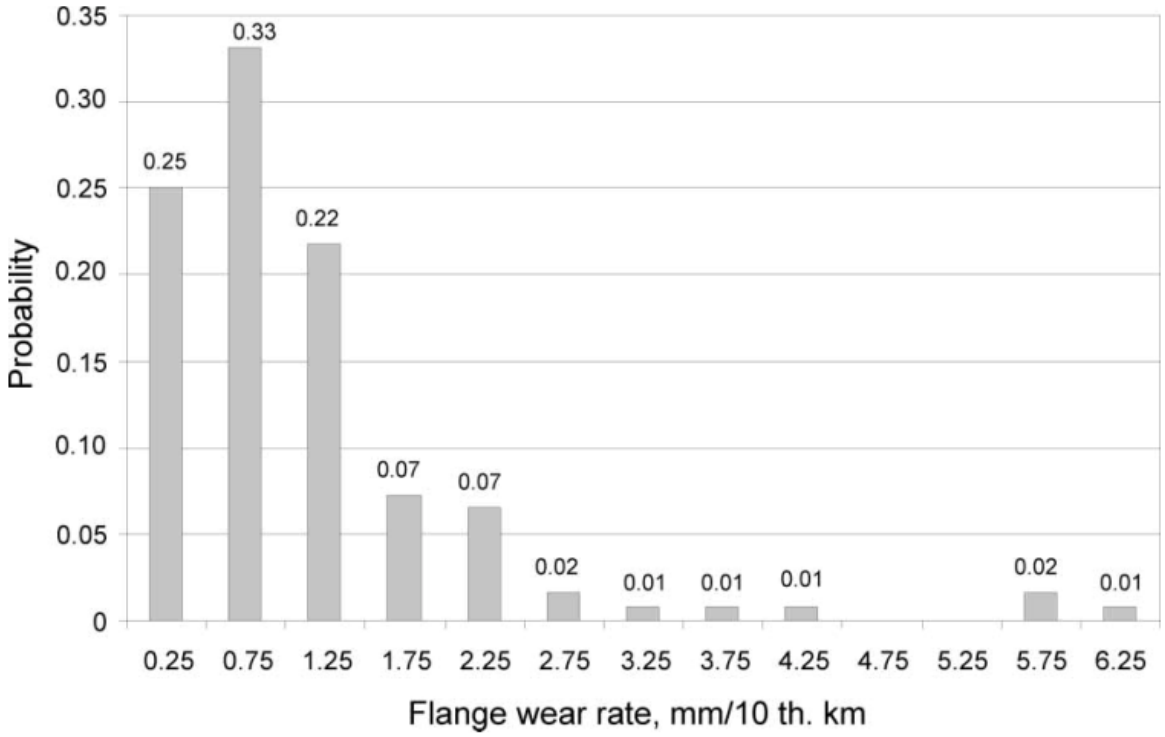


Figure 16. Effect of Track Quality on RCF Damage – FSA with Y25 Bogies

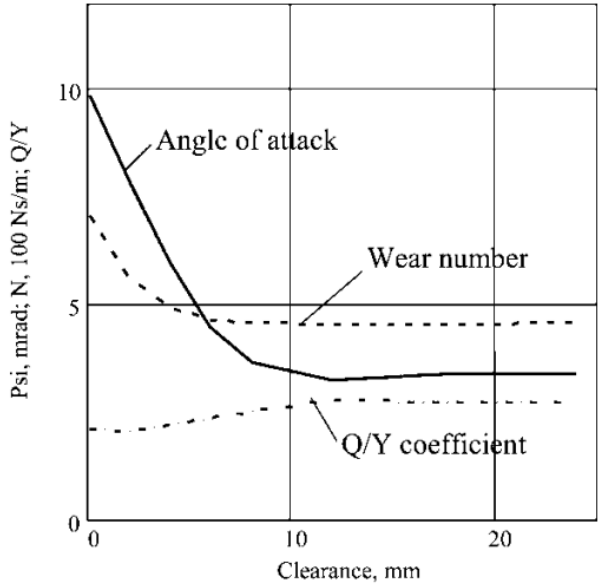
Ref: Stichel S; Bosso N; Tunna J.

Test results from literature:

Higher wear rates by flanging in three-piece bogie



Ref: Orlova A; Boronenko Yu.

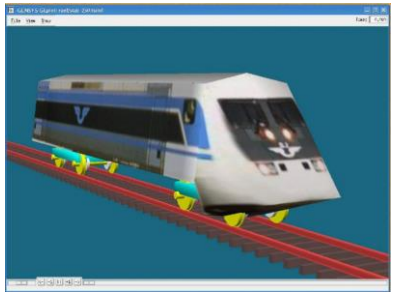


Seventy percent of gondolas have flange wear rate below **1.25 mm/10,000 km**. Three-piece bogies have caused **more side wear in rails** at small and medium radius curves in Finland.

Field Measurements:

- On-site tests were also carried out recently near **Kouvola** for different freight wagons (loaded and unloaded).
- The dynamic behaviour of the wagons was studied in a tight curve of radius 200m.
- Vertical and Lateral wheel-rail forces; Longitudinal forces; Angle of attack of all the wheels; and the wheel profiles were measured.
- Such on-site tests provide valuable real time data on the performance of the bogies.

VAMPIRE PRO



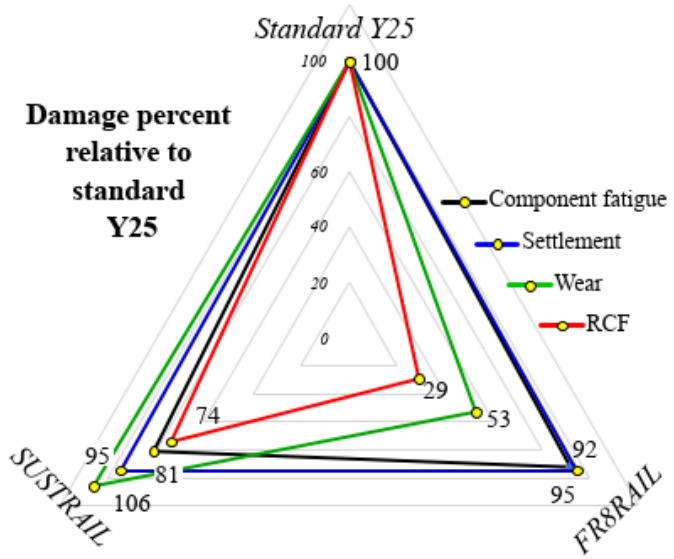
Current Phase of the Project:

- Identifying the **situations** that are most important to analyse, such as curve radius and running speed.
- Finding which **parameters** are the most important to consider, such as forces, wear, accelerations, vibrations, etc. Other things that may have a larger impact in some circumstances are the wheel profile, rail profile, gauge, track irregularities, track stiffness, wheel faults, etc.
- **Placing** these quantities in order: which are the most relevant and which property makes one bogie perform better than another.
- **Simulations** estimates for example forces, sliding forces, energy function Tγ, angle of attack, location of wheel set, etc. The idea is to find out the circumstances in simulations that show the biggest differences.

Literature review → Critical Parameters → Simulations → Framework

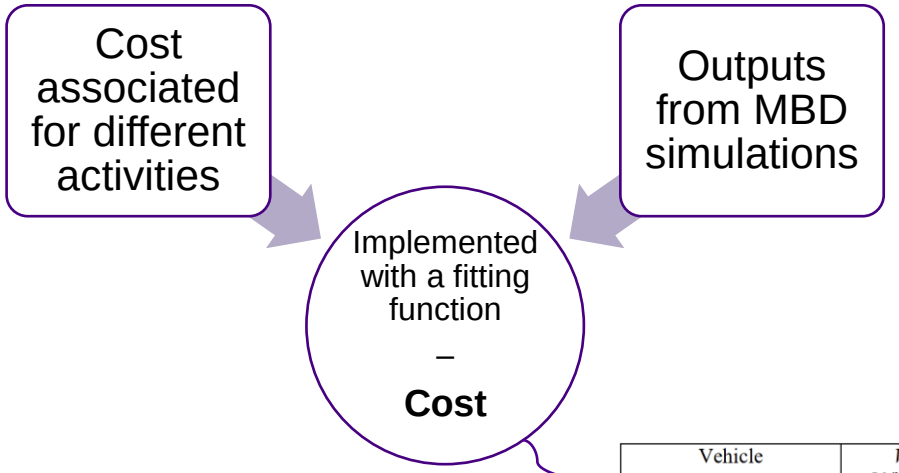
Illustrations of track-friendliness from literature:

1.



Using the outputs from simulations to put out qualitative indicators of the track-friendliness for the running gear….

2.

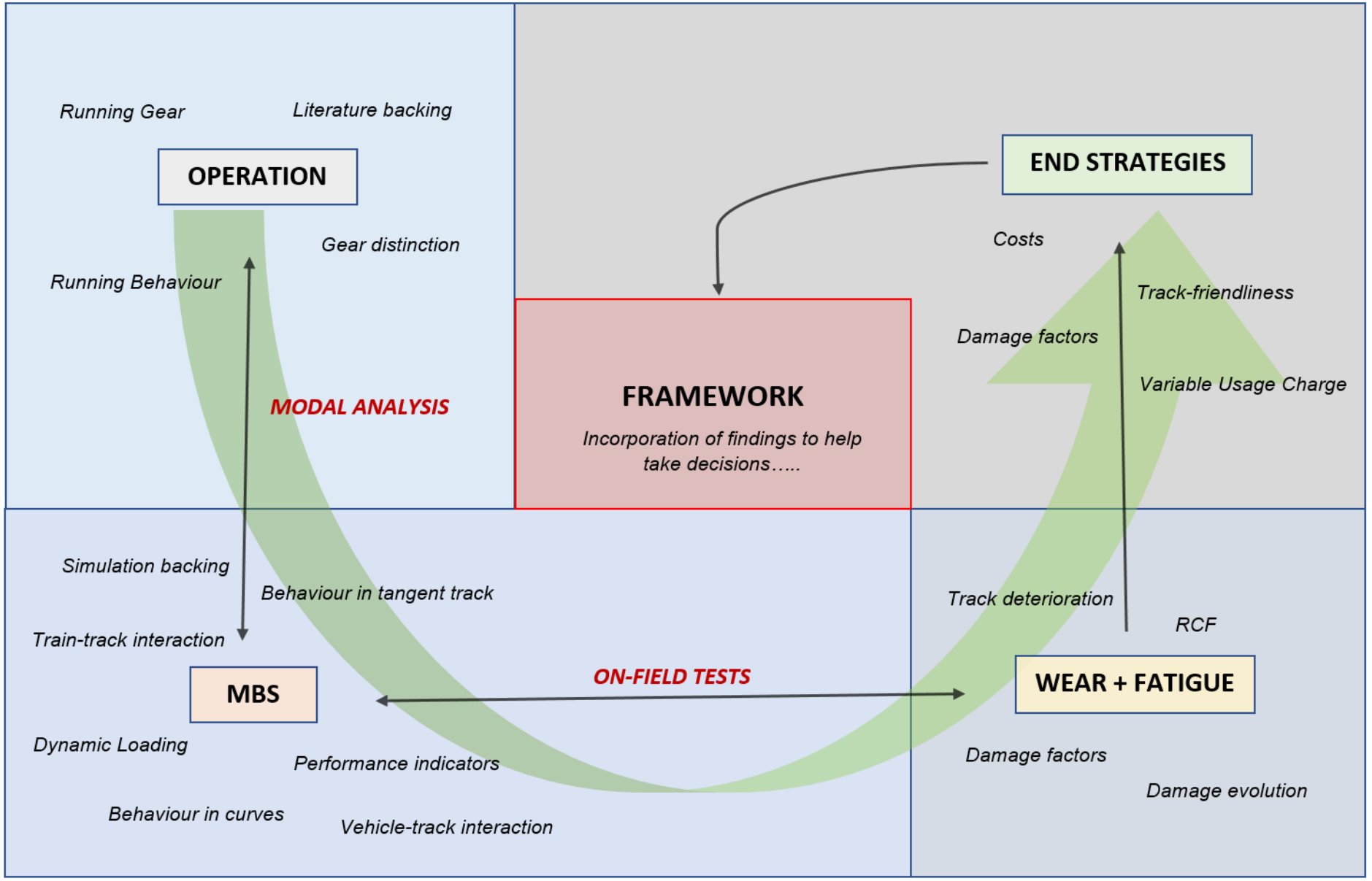


Vehicle	*VUC* [£/kGTM]
Y-series reference	1.5242
New bogie	1.1046
Spectrum reference	1.3585

Track access charge is determined by using the simulation outputs like the Tγ values and suitable deterioration costs with a fitting function per gross ton-km.

Ref: Bracciali A; Visakh V

Summary


Running Gear
Literature backing
OPERATION
Gear distinction
Running Behaviour
MODAL ANALYSIS
END STRATEGIES
Costs
Track-friendliness
Damage factors
Variable Usage Charge
FRAMEWORK
Incorporation of findings to help take decisions…..
Simulation backing
Behaviour in tangent track
Train-track interaction
MBS
ON-FIELD TESTS
Track deterioration
RCF
WEAR + FATIGUE
Dynamic Loading
Performance indicators
Behaviour in curves
Vehicle-track interaction
Damage factors
Damage evolution

Thank you for your attention…..

Questions???