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Universal Cost Model: railway system interdependencies in LCC analyses

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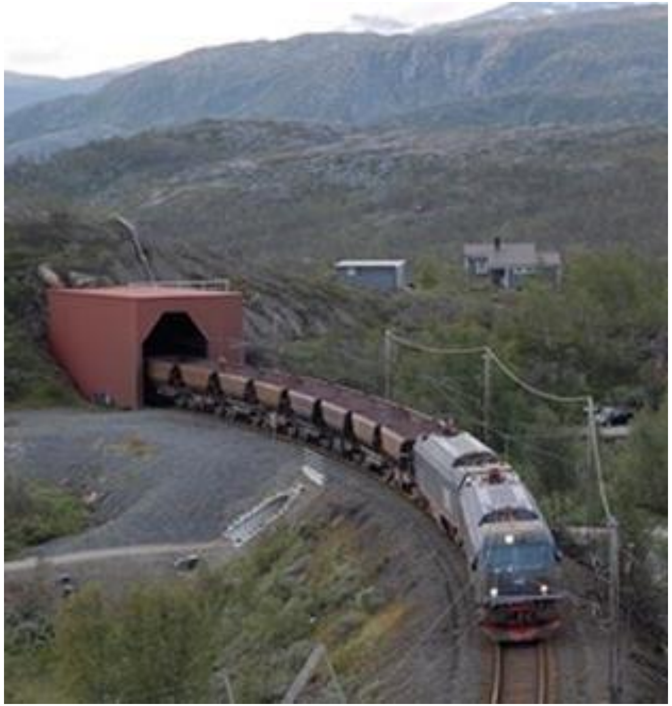
Agenda

- What is the Universal Cost Model
- Innovation modelling in LCA contexts
- Case study 1 – single wheelset running gear with active suspensions
- Case study 2 – Decision-making support for novel block brakes
- Case study 3 – reprofiling strategies
- Conclusions and further work

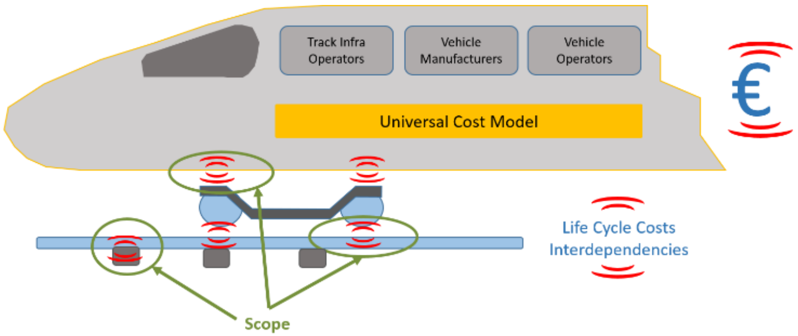


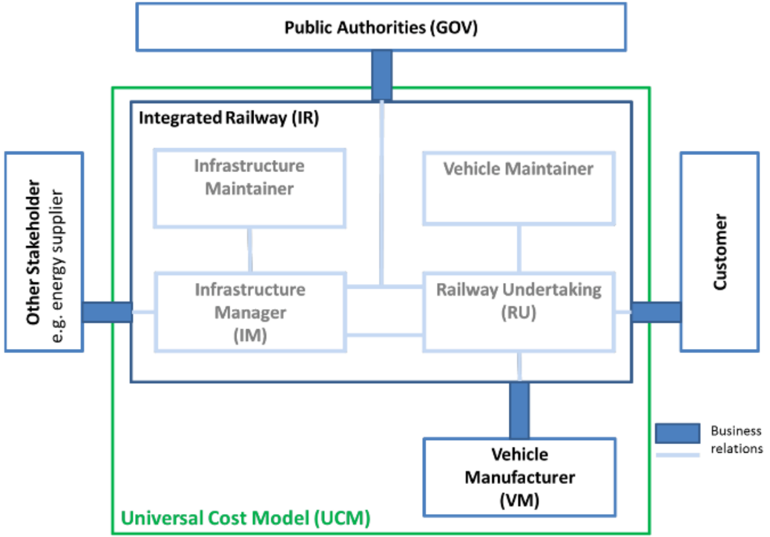
NEXTGEAR project

- Shift2Rail Open Call project
- WP1 – Universal Cost Model 2.0

Universal Cost Model (UCM)

- Methodology developed in the EU project Roll2Rail and updated in NEXTGEAR
- Demonstrate and quantify the **global impact** of running gear innovations
- Considers the **differential costs** from running gear modifications in different rail system stakeholders

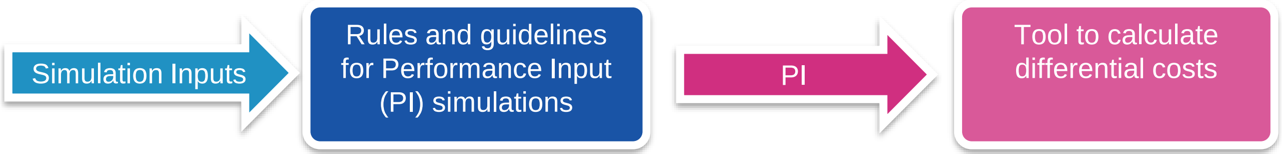




UCM methodology and architecture

Methodology:

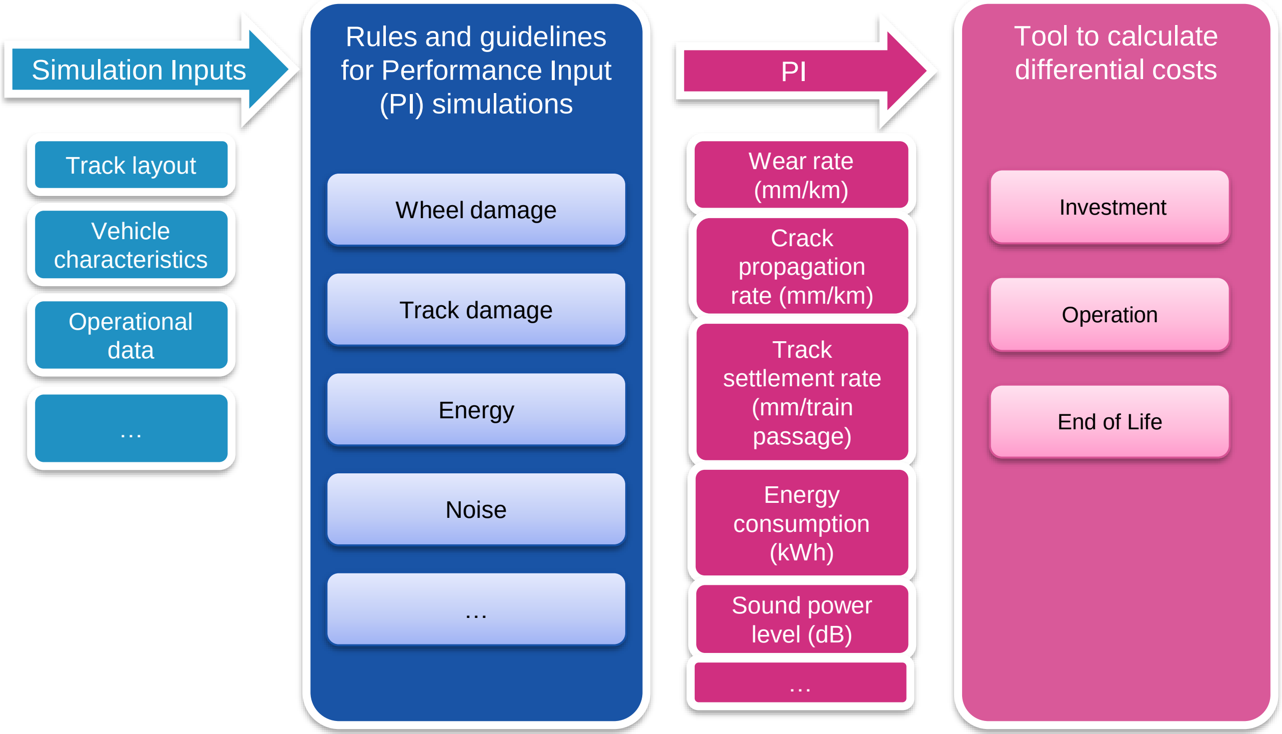
- Proposes methods to simulate cost generators (Performance InputsPIs)
- No specific tool for this, just guidelines



Tool:

- Excel file
- Gathers all the KPIs and converts them into costs
- Extensive information is needed for the cost calculations

What is the UCM



UCM tool modules and simulation of Performance Inputs (PI)

Potential Hazards	Energy
Noise	Vehicle Maintenance
Rail Maintenance	S&C Maintenance
Ballast Maintenance	End of Life cost modelling

POTENTIAL HAZARDS MODULE

SPD1-HS	Case 1	Case 2	
€ 2 400.00	€ 2 400.00	€ 2 400.00	€/vehicle/year

Performance Inputs

Cost due to different types of unavailability is calculated based on the following key inputs:

Performance Input Description	*PI*	*SPD1-HS*	*Case 1*	*Case 2*
Probability of Hazard per unit per year (-)	PI_PH	0.00001		

The user can input their own simulated Pis for Case 1 and Case 2 in order to compare different vehicle designs.
See the *Simulation Guidelines* document for further information on the simulation of Pis.

Cost calculation

The module calculates the costs of Potential Hazards based on the estimated probablility for a hazardous event per year per unit.
For a full description of the calculation procedure refer to the *User Manual.*

$$CH = PI\_PH \cdot CH\_u \cdot u_V \qquad \text{(H.1)}$$

Calculation Options

The following inputs and options are used for the calculation of the Module costs.

Global Inputs

These are defined in the ***Case Selection*** page and cannot be modified here as they affect different Modules.

Global inputs	*I*	*SPD1-HS*	*Case 1*	*Case 2*
Number of units per vehicle (-)	u_V	8	8	8

Module Inputs

These are specfic for this module and the user can thus insert own values here:

Module inputs	*I*	*SPD1-HS*	*Case 1*	*Case 2*
Indemnities and compensations per H1 (€)	CH-u	€ 30 000 000.00		

Additional Options

In order to adjust the module to User needs, the following options are available:

There are no futher options available.

Additional Information

This section includes information that is used in the calculation of the Module costs that is not editable by the user.

Pre-calculated Performance Inputs (PI)

Performance Inputs	*I*	*SPD1-HS*	*SPD2-Regional*	*SPD3-Metro*
Probability of Hazard per unit per year (-)	PI_PH	0.0010%	0.0010%	0.0010%

SPD Module Inputs

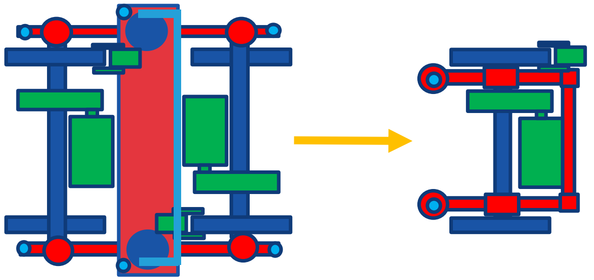
These are the Module Inputs for the different SPD:

Module inputs	*I*	*SPD1-HS*	*SPD2-Regional*	*SPD3-Metro*
Indemnities and compensations per H1 (€)	CH	€ 30 000 000.00	€ 30 000 000.00	€ 30 000 000.00

End of Module

Case study 1: NEXTGEAR vehicle

Metro vehicle
Active steering
Composite bogie frame



Standard Bogie

Single Axle Frame

Property	Class 8000	2-axle vehicle
Max. speed	120 km/h	120 km/h
N. cars	3	5
Length	55 m	60 m
Payload per meter	1,000 kg/m	1,000 kg/m
Tare weight per meter	1,900 kg/m	1,500 kg/m

- Potential Hazards
- Energy
- Noise
- Vehicle Maintenance
- Rail Maintenance
- S&C Maintenance
- Ballast Maintenance
- End of Life cost modelling

Case study 1: NEXTGEAR vehicle

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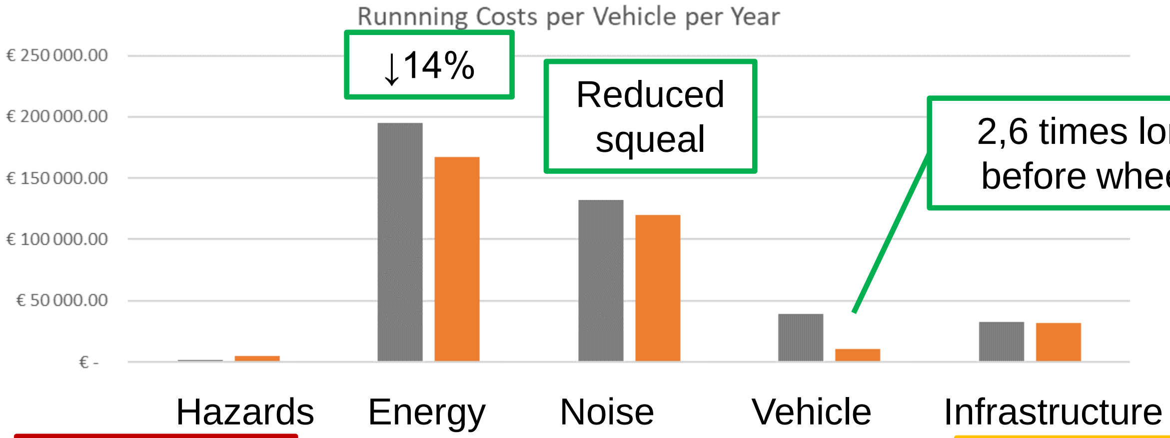


↓14%

Reduced squeal

2,6 times longer mileage before wheel reprofiling!

Slightly less reprofiling depth

More complex running gear

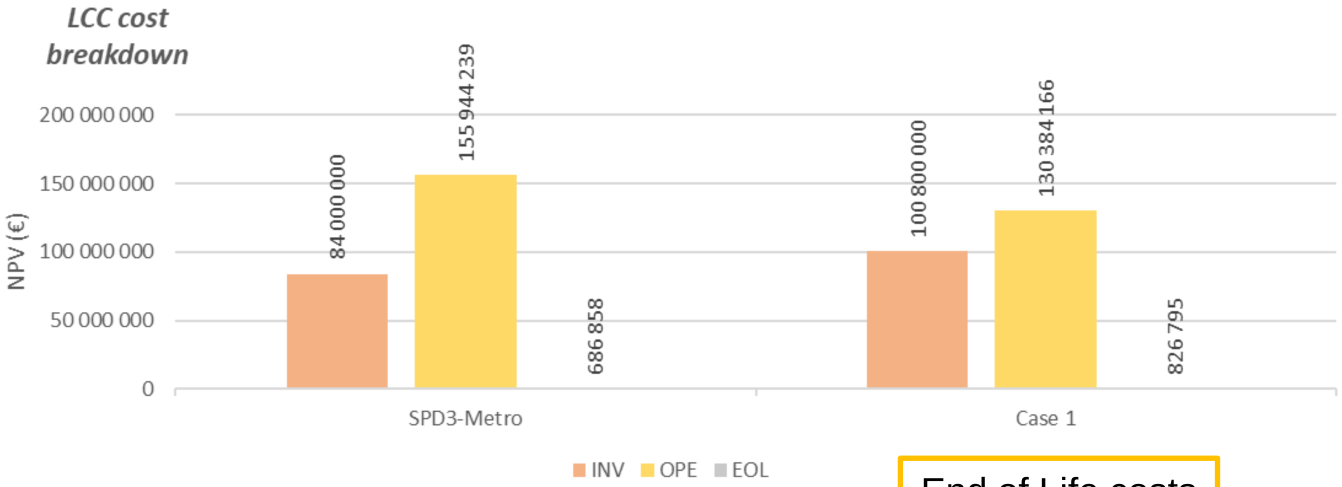
Non-ballasted track

Case study 1: NEXTGEAR vehicle

Metro vehicle
Active steering
Composite bogie frame

Cost per veihcle per year

€ 15 608 717	€ 15 038 862
SPD3-Metro	***Case 1***



Investment Operation EoL

End of Life costs not significant

Case study 2: Novel block brakes

Freight vehicles
Cast iron vs. Composite block brake materials

New block brake materials → Reduced wheel roughness → Reduced rolling noise

Drawbacks

- New blocks wear out the wheels much faster
  - Increased wheel maintenance (sector estimations of ca. 10M€ per year)
  - Worsened wheel-rail profile match increases dynamic forces
  - Track deterioration might be accelerated
- In specific climatic conditions –Nordic Conditions–, these new materials have reduced braking capabilities – safety issue
- Operational consequences – limitation of max speed during winter – capacity issue

Case study 2: Novel block brakes

Freight vehicles
Cast iron vs. Composite block brake materials

- Intended effect: noise reduction
- Secondary effects
  - Increase in Potential Hazards
  - Increase in Vehicle Maintenance
- Unsure about many of the knock-on effects
  - Increased track forces?

Potential Hazards

Energy

Noise

Vehicle Maintenance

Rail Maintenance

S&C Maintenance

Ballast Maintenance

End of Life cost modelling

Wheel maintenance

- Reprofiling mileage due to wear decrease (need to reprofile sooner)

Wheel	Mileage	Trigger
Old	549 500 km	Flange height > 36 mm
New1	272 000 km	Flange height > 36 mm
New2	362 000 km	Flange height > 36 mm

- However, the wheel reprofiling is due to RCF cracks, which appear sooner

Wheel	Average reprof. mileage
Before 2010 (old)	74 974 km
After 2010 (new)	100 130 km

← Vehicles with novel brakes have a LONGER reprofiling distance because they remove the RCF cracks!

Wheel damage costs

- UCM differential costs

	Old	New1
Km between reprofiling	74 974 km	100 130 km
Material removed	4,73 mm	6,10 mm
Total reprofiles for yearly operation	1,80	1,35
TOTAL COST PER YEAR PER VEHICLE	**34 047,86 €**	**26 365,67 €**

- Higher reprofiling distance
- Higher material removal due to hollow wear
- Result: reduced reprofiling costs

Contradicting effects

Final result is system dependant

Case study 3: Wheel reprofiling

Metro vehicle Alternative Wheel reprofiling strategies

- Reprofiling strategy a combination of:
  - limit flange thickness, SdP
  - flange thickness after reprofiling, SdR

Case 1, SdP= 26 mm and SdR= 29 mm
- Wheelset reprofiling mileage (km): 185.950 km
- Wheelset reprofiling depth (mm): 5 mm

Case 2, SdP= 26 mm and SdR= 32 mm
- Wheelset reprofiling mileage (km): 393.870 km
- Wheelset reprofiling depth (mm): 9.68 mm

Total costs per veihcle per year

€ 12 024 852	€ 11 516 176	€ 11 334 567
SPD3-Metro	***Case 1***	***Case 2***

Highlights

- Innovations in running gear have effects in many stakeholders at different stages in time
- Innovative concepts cannot be compared to existing ones without a prototype
- The Universal Cost Model allows to compare these innovations without the need of tests
- Three study cases have been presented
  - Novel single-axle and active suspension running gear for metro vehicles
  - Decision-making support for novel block brake materials for freight vehicles
  - Alternative wheel reprofiling strategies

The cases highlight the UCM methodology as a powerful and flexible tool to analyse system interdependencies when intruducing innovative running gear solutions

Thanks for listening!

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