Survey of maintenance practices and costs

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Overall objectives of WP6

- **Objective**: To review and analyse the market uptake of different solutions to minimize the risk of failure of axles developed during the present project.

- The assessment will follow RAMS/LCC methodologies, a recognized method for assisting optimisation process in engineering systems.
- **RAMS** – Acronym Reliability, Availability, Maintainability and Safety
- **LCC** – Acronym for Life Cycle Costs
  - LCC stands for the costs of a system throughout all the phases of its life, from conception to disposal.

RAMS/LCC in railways

Introduction

- RAMS/LCC can be used to compare different alternative solutions.
- RAMS/LCC applied in several sectors like automotive and aerospace.
- Incipient in the railway industry.
- Reasons:
  - Different roles of the stakeholders so the transmission of information is not effective.
  - Analysis rely on experimental data – difficult, lengthy and costly to obtain.
- European railway sector is moving towards the systematic application of these techniques as demonstrated by the publication of e.g. EN 50126.

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RAMS/LCC in railways - Survey

Survey – Results

- Most of the participants calculate RAMS/LCC regularly and some have RAMS specialists in the company.
- Operators consider RAMS/LCC requirements in their contracts for the complete vehicle but not specifically for the wheelsets.
- Integrators specify RAMS/LCC parameters in the contracts including the wheelset which are then translated to the manufacturers.
- In the vast majority, the participants use their own databases to manage the RAMS/LCC parameters.
- There is a lack of feedback from operators and maintainers to manufacturers. This fact is one of the main difficulties to improve the railway transport competitiveness.
- In many cases, the tools and information given by the manufacturers are provided by the customers so they are considered as confidential.
- Most participants use their own RAMS analysis software (basically Excel).

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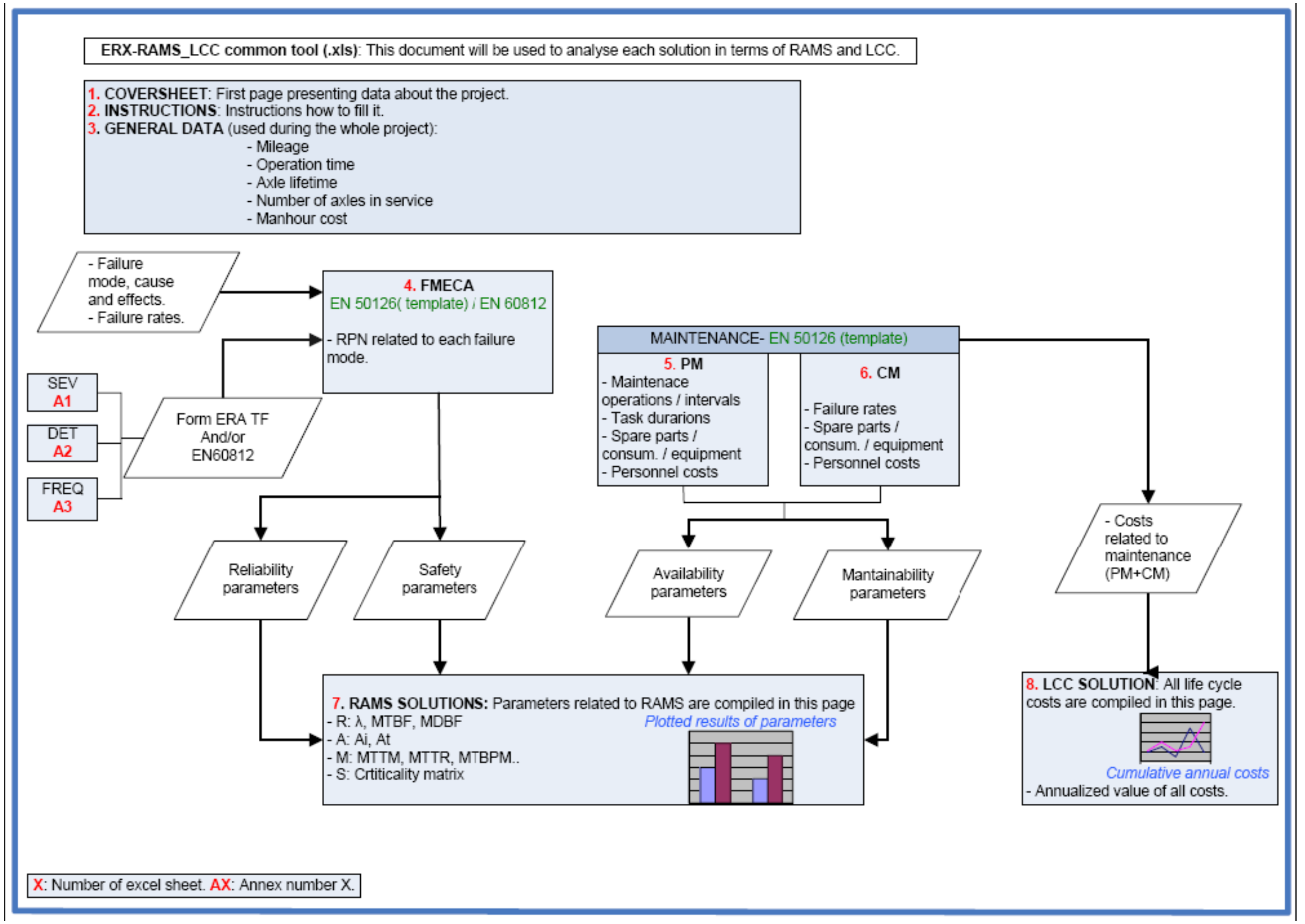
RAMS/LCC tool - Definition

Requirements derived from the survey

- Excel tool
- FMECA should be considered for safety analysis.
- For LCC calculations, acquisition and operational costs should be considered as they represent the most relevant phases affecting the LCC of axles.
- Maintenance costs should cover both preventive and corrective maintenance.

RAMS/LCC tool - Definition

Tool – General chart



RAMS/LCC tool - Definition

Safety

- FMECA and RPN (Risk Priority Number)
- A target value for RPN to determine quantitatively the risk is not attainable at this moment due to the lack of accurate data from service
- FMECA applied to categorize the failure modes and effects and to prioritize efforts.
- Basis for the future to get accurate data for risk calculation.

			CRITICALITY - Curent state						
Failure mode	*Failure root cause*	*Failure rate (FPMK)*	*Severity*		*Detectability*		*Frequency*		*RPN*
Fatigue crack	**Combination of all causes**	**8,000E-03**					Very high: Failures are nearly not avoidable (10)	10	
	Overloading of the wagon	1,000E-03	Unsafe without warning	10	Nearly certain	1	High: repeating failures (8)	8	80
	Overloading by dynamic effects	1,000E-03	Unsafe without warning	10	Nearly certain	1	High: repeating failures (8)	8	80

Risk Priority Number (RPN) = S * D * F

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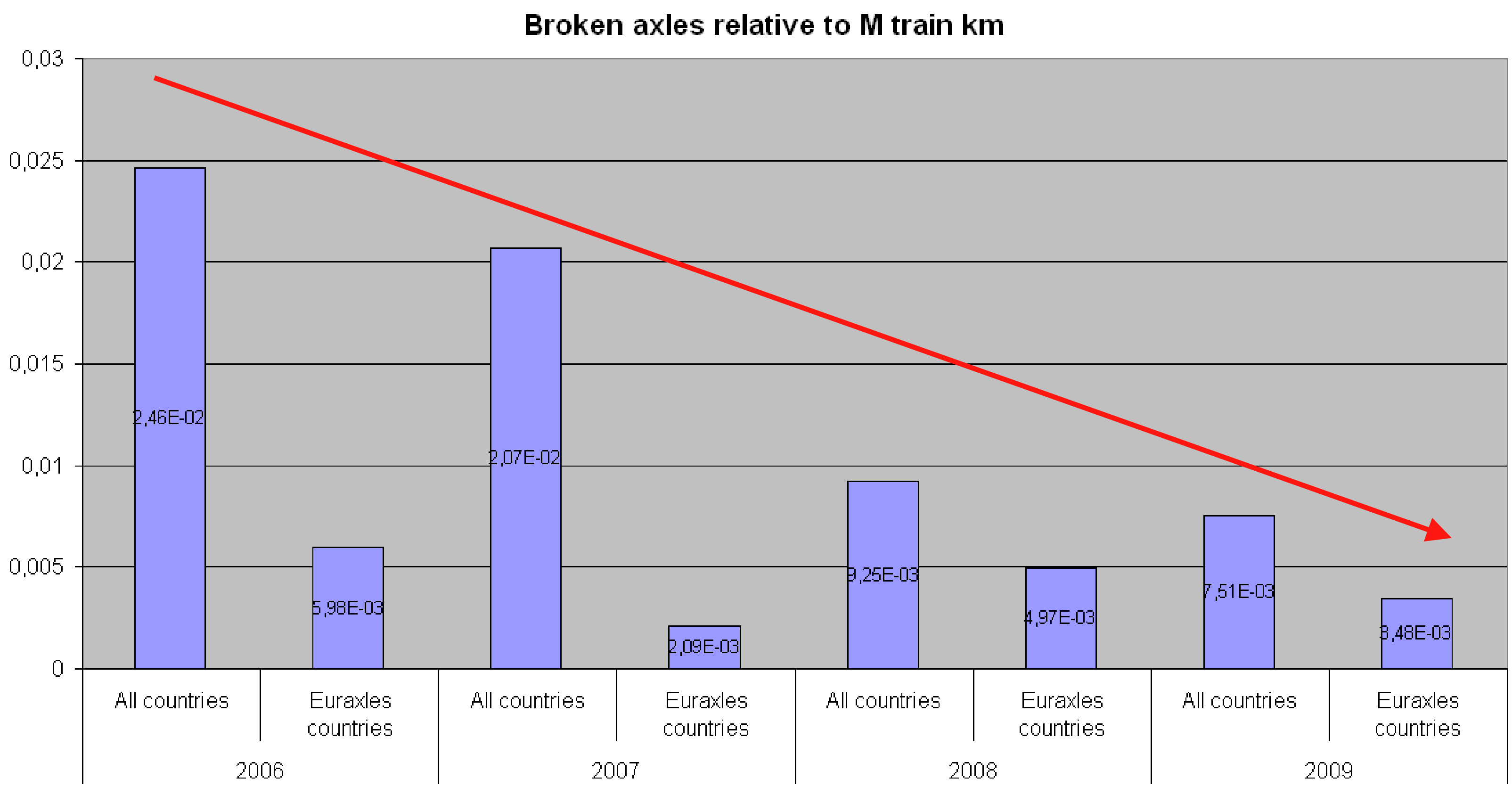
Data collection – Analysis of axle failures
Introduction

- Aim: To collect data from service to define reference cases.
- Limited data available.
- Analysis of databases and reports has been performed to estimate the reliability of axles.
  - ERADIS 2011
  - UIC Safety database 2011
  - JSG Task force in freight wagons 2012

Data collection – Analysis of axle failures

Failures

- ERADIS (2006-2009):



Data collection – Analysis of axle failures

Failures

- JSG (last 50 years):

Bochumer Verein: Germany

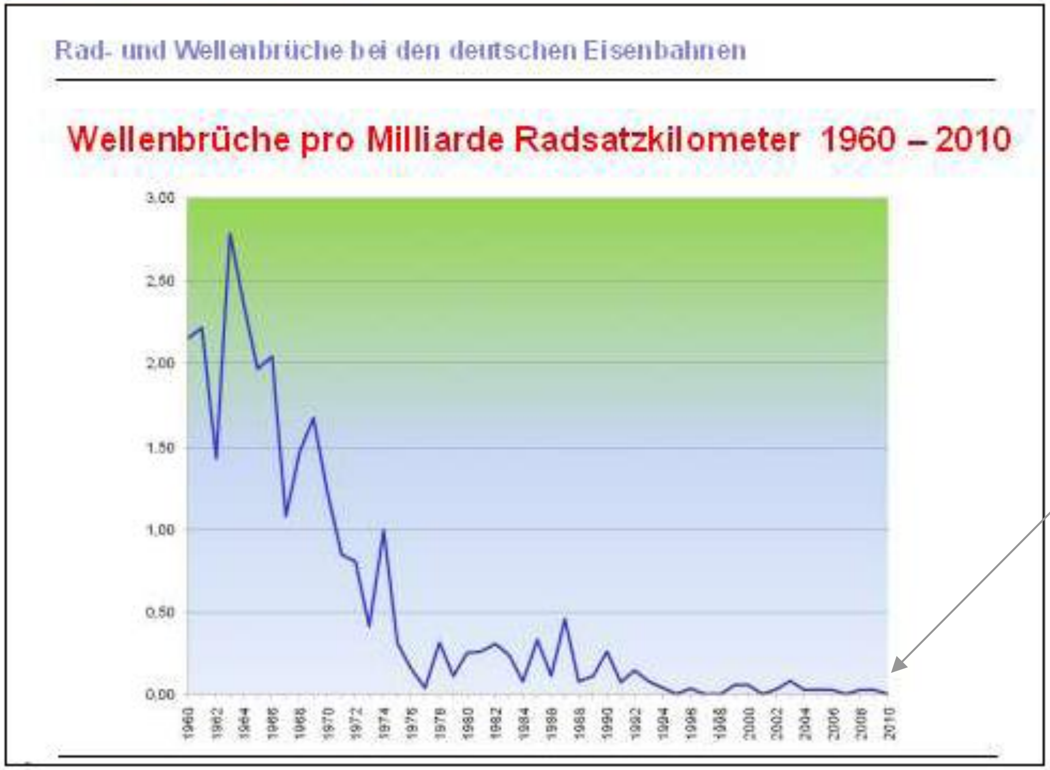


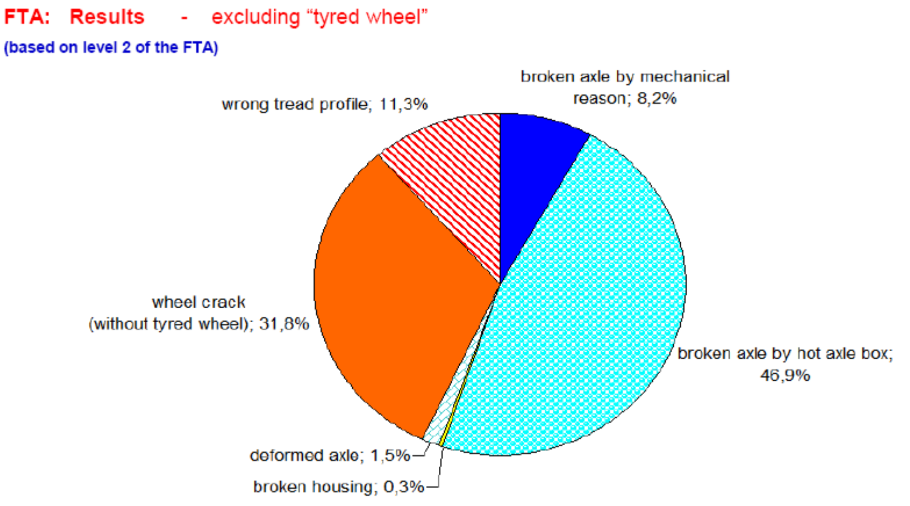
Figure 4: number of axle breaks per billion wheelset kilometers between 1960 - 2010

Safety of today's railway traffic is very high

Data collection – Analysis of axle failures

Failures

- JSG risk analysis:
  - 57 % due to axle failures (of which 47 % related to hot axle box, 2 % to deformed axles and 8 % to other causes)
  - 32 % due to wheel failures
  - 11 % due to wrong tread profile
- The majority of broken axles is linked to problems with the bearings.



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Data collection – Reference cases

Data collection

- Preventive and Corrective Maintenance questionnaires distributed
  - Euraxles partners
  - EUAG
- Reliability data of axles is not commonly available within the operators so the study must rely on expert estimations
- Significant scatter of maintenance practices among the different companies and applications showing the lack of harmonization of maintenance rules in Europe
- According to the received data, CM < 5% total LCC
- LCC analysis based only in PM

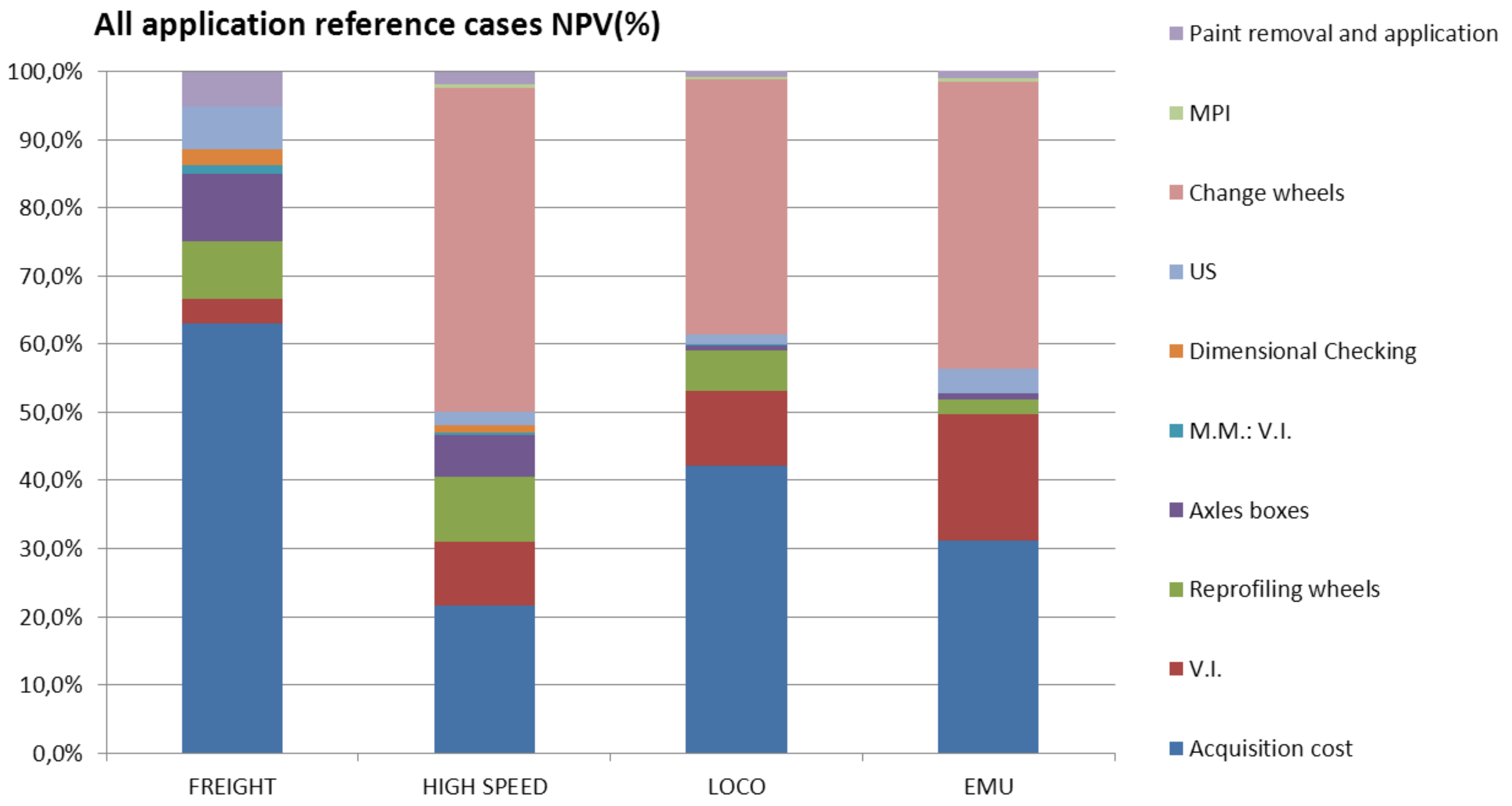
Data collection – Reference cases

Results

	FREIGHT	HIGH SPEED	LOCO	EMU
Mileage/year	**30.000 km**	**300.000 km**	**150.000 km**	**175.000 km**
Lifetime	**40 years**	**30 years**	**30 years**	**30 years**
NPV annual	**139 €**	**1.766 €**	**1.106 €**	**828 €**
NPV / 1.000 Km	**4,62 €**	**5,04 €**	**7,38 €**	**4,73 €**

Coating	Class 3	Class 3 (2 comp)	Class 3	Class 3
US technique	Automatic system - Axle surface	Semiautomatic system bore– Hollow axle	Semiautomatic system – Axle end	Semiautomatic system – Axle end

Data collection – Reference cases
Results



Data collection – Reference cases

Results

- Highest cost contributions:
  - Wheels substitution
  - Acquisition
  - Axle related operations ≈ 15% - 25 % of costs
- Class 3 coatings considered as reference solution in all applications
- Reference US inspection depends on the application
  - Freight: Automatic system on the axle surface
  - High speed: Semi-automatic system from bore (hollow axle)
  - Loco & EMU: Semi-automatic system from axle end

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- **Innovative coatings**
- LCC parametric analysis
- Reliability and cost analysis
- Conclusions

Coatings – Current and innovative solutions

Cost and maintenance information - Summary

- Lack of expertise of application of innovative coatings in railway axles
  - New production
  - Maintenance
- Ni/SiC electrodeposition and HVOF high costs
- Costs of ZnAl thermal spraying comparable to conventional coatings
  - Additional top coat for protection against mechanical damages (manipulation, etc.) probably needed . Costs increased
- Further investigations recommended

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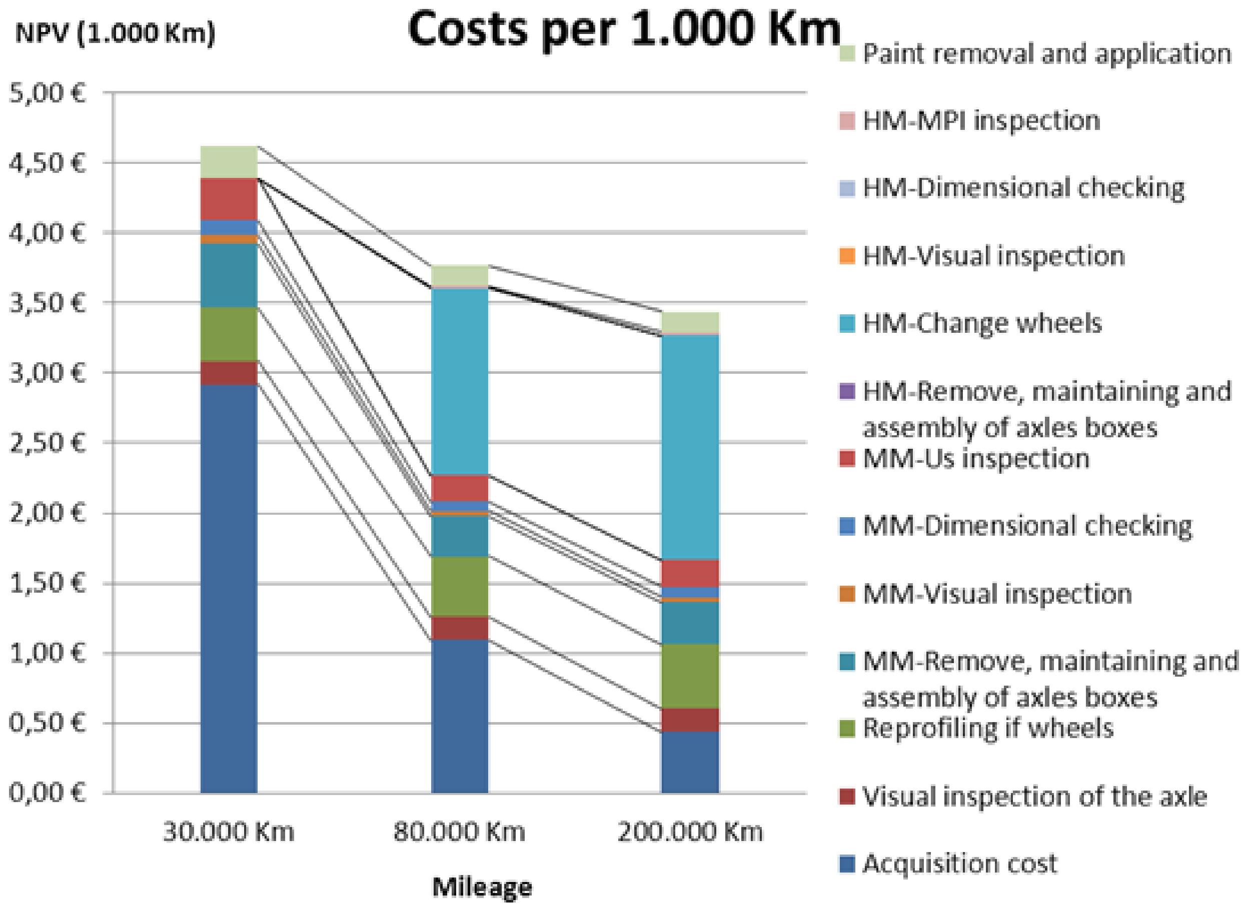
LCC parametric analysis
Motivation and parameters

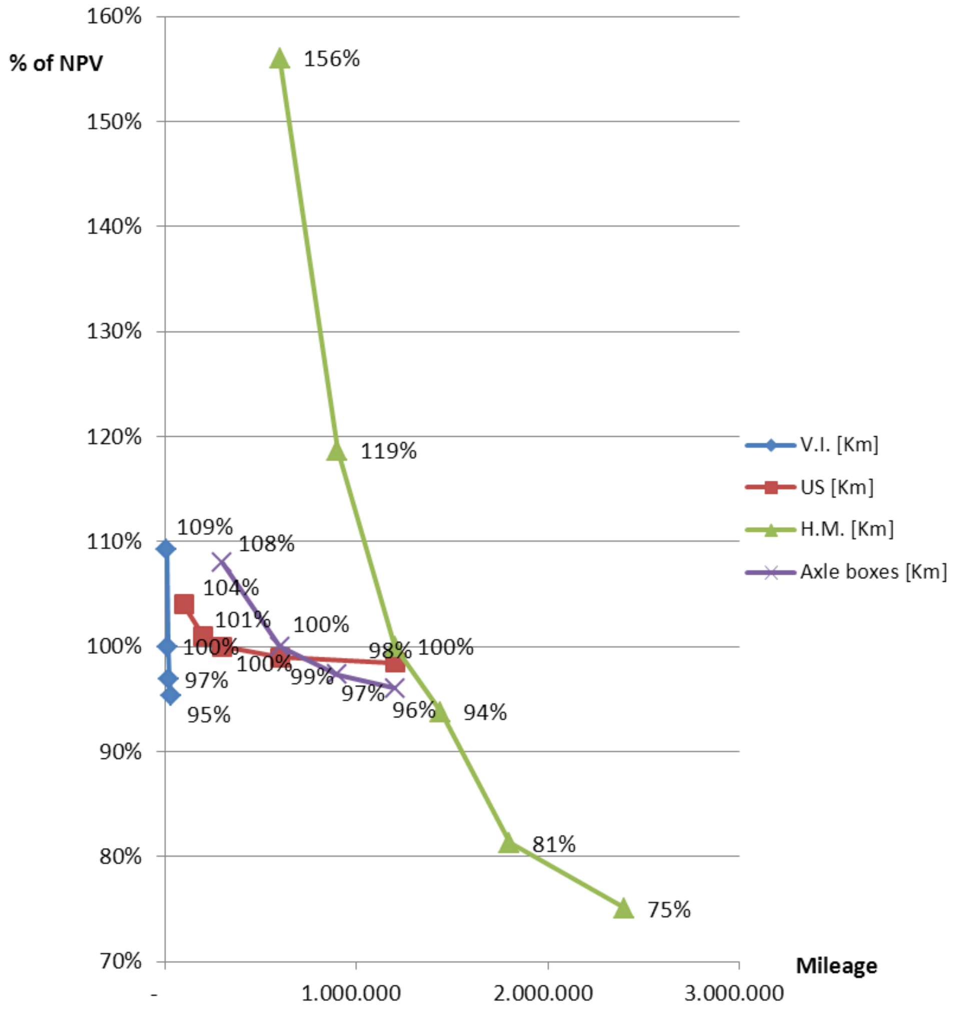
- Parametric analysis to estimate the trends which lead the optimization of LCC for different applications
- Parameters:
  - Km/year
  - Visual inspection [Km]
  - Axle boxes [Km]
  - US inspection [Km]
  - Heavy maintenance [Km]
  - Different US techniques (hollow, axle-end, axle body surface)
  - Coating: Class 3 Vs Class 3 + Class 1
    - Conclusions applicable to innovative coatings

LCC parametric analysis
Freight



LCC parametric analysis

High speed



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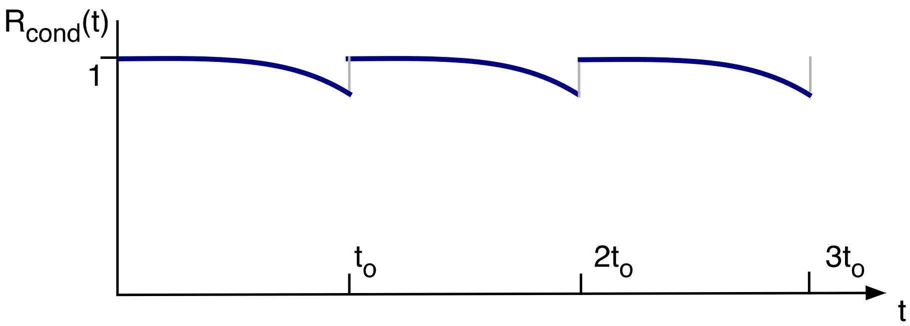
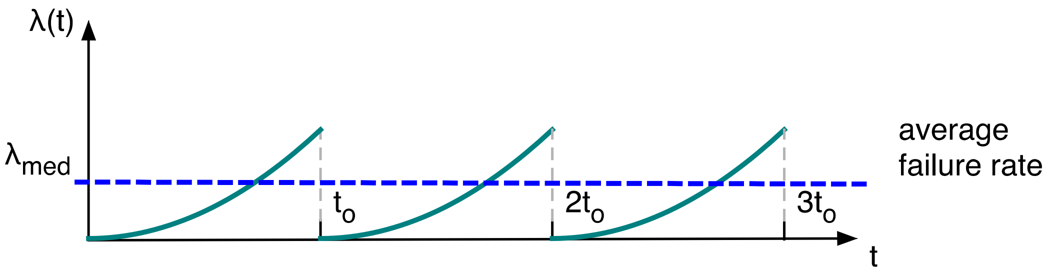
Reliability and cost analysis

Introduction

- Maintenance operations to “restore” the condition of the axles
- Conditional reliability



- Failure rate

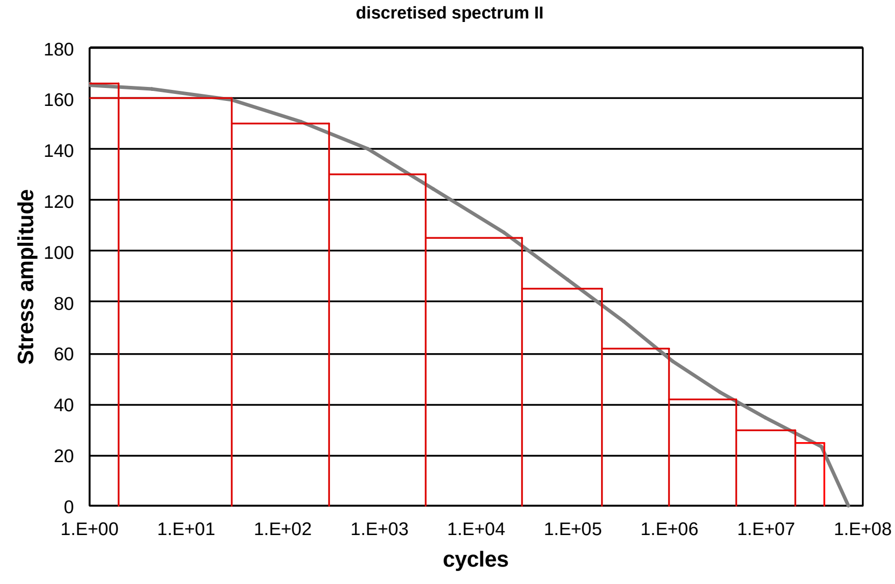


$$\lambda_{med,EN1990} = 2 \cdot 10^{-6} \quad [\text{failure/year}]$$

$$\lambda_{med,target} = 2 \cdot 10^{-7} \quad [\text{failure/year}]$$

Reliability and cost analysis
Reliability analysis

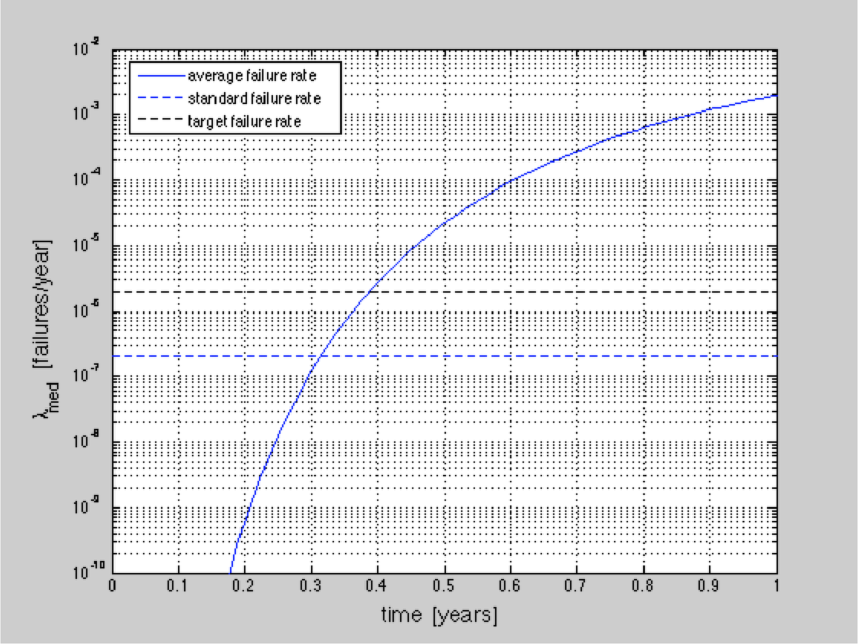
- Calculation
  - Reliability vs. time for a given spectrum
  - Derivation of reliability for obtaining the failure rate
- Application: High speed (HYPERWHEEL)
- Damages considered in the analysis:
  - Corrosion
- Mileage = 350.000 km/year



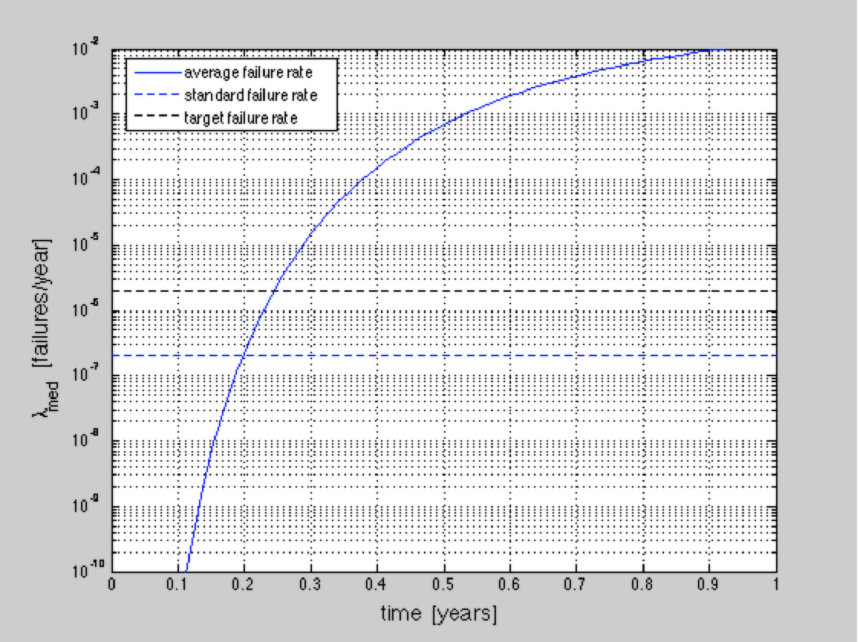
Reliability and cost analysis

Reliability analysis - Results

Smax = 210 MPa



Smax = 230 MPa



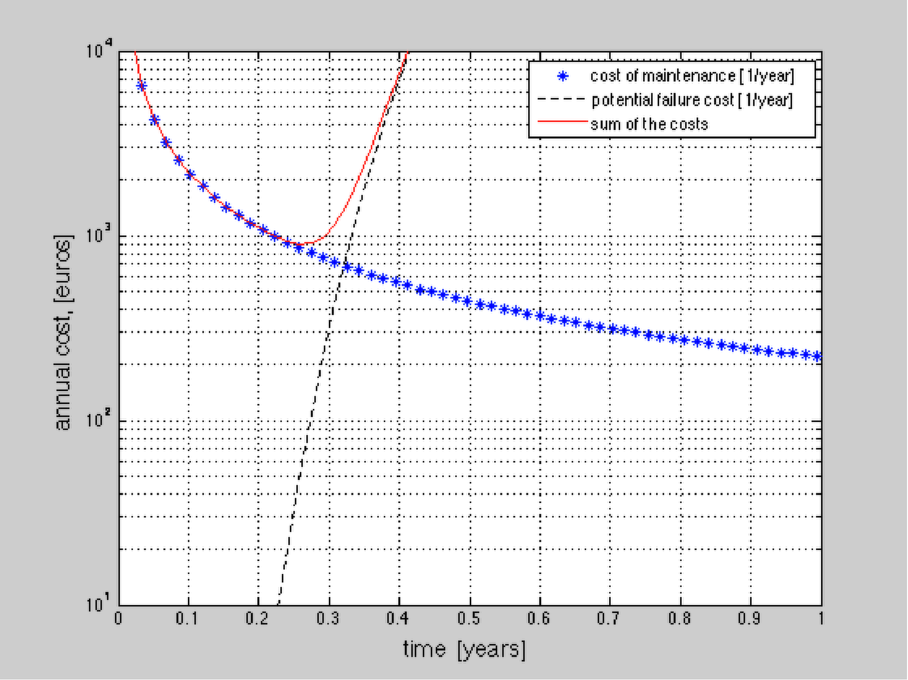
- Standard failure rate: 140,000 km;
- Target failure rate: 100,000 km

- Standard failure rate: 88,000 km;
- Target failure rate: 70,000 km

Reliability and cost analysis

Reliability and cost analysis - Results

Smax = 210 MPa



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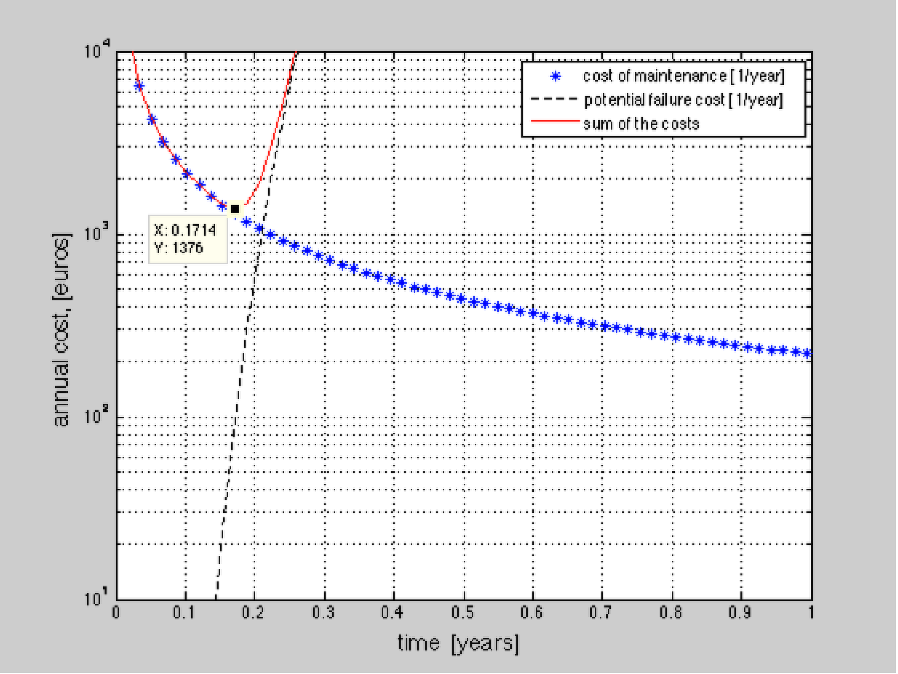

- Intersection point: 110,000 km (≈ periodicity for target failure rate
- Optimum: 85,000 km

- Intersection point: 70,000 km (≈ periodicity for target failure rate
- Optimum: 59,000 km

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Conclusions

- Significant scatter of maintenance practices among the different companies showing the lack of harmonization of maintenance rules in Europe.
- LCC distributions of several applications have been calculated. Axle related operations depend on the application.
- Costs of innovative solutions have been estimated. Further investigation recommended for application in railway axles.
- LCC parametric analysis to assess the influence of maintenance operations performed.
- Method for risk analysis linked to cost calculations for determining the optimal inspection intervals proposed.
  - Intervals depend on the maximum stress of the spectrum

Conclusions

- According to the return of experience, the risk to have axle failures in actual railway traffic is very low so the safety is very high .
- Collaboration between different undertakings for further improvement of the reliability and maintenance of axles.

Thank you for your attention