INFRALERT

RAMS & LCC Toolkit

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cemosa
Ingeniería y Control

Agenda

- Introduction

  Concepts and Objectives

- RAMS&LCC Methodology

  Data processing and calculation

- Implementation

  Programming details: computing language and main libraries

- Results

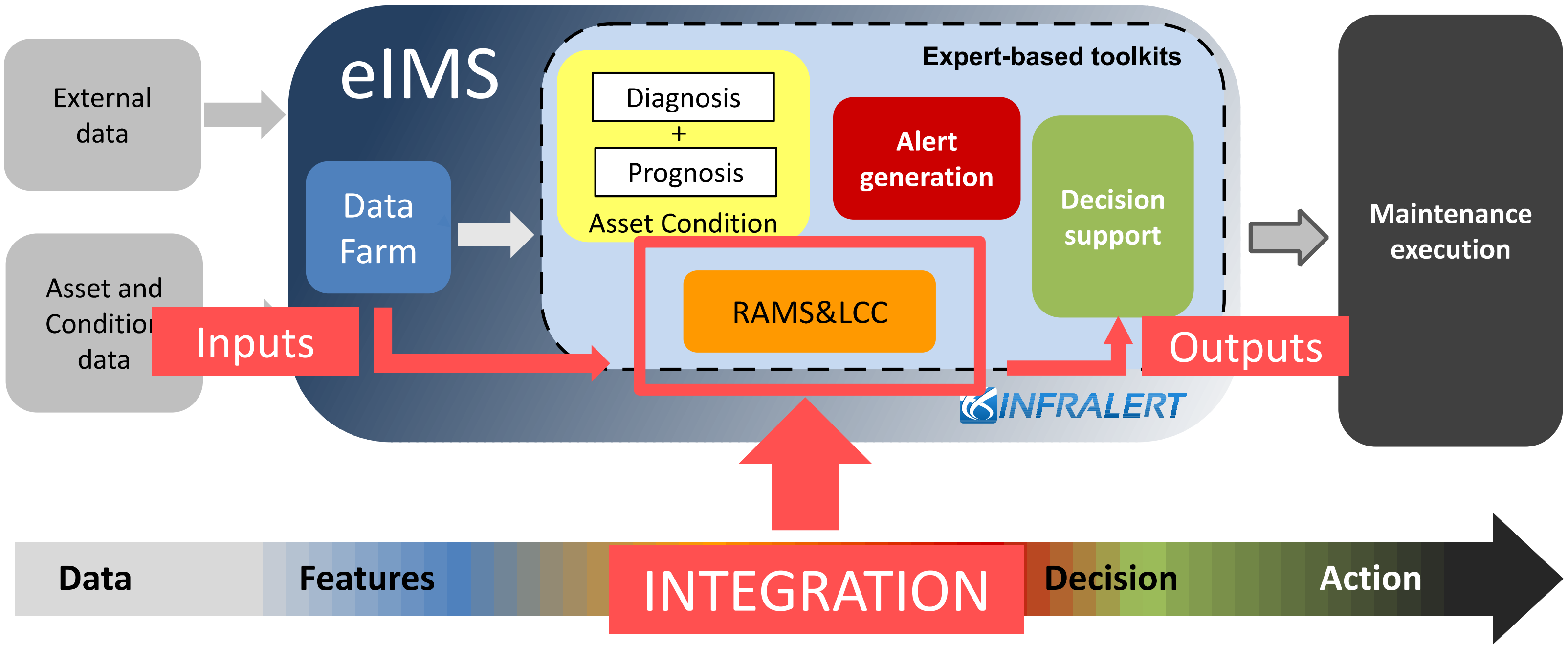
  Road application (pavement) – Portugal demo

  Rail application (S&C) – Sweden demo

- Conclusions and next steps

Introduction. General overview.

- Aim of INFRALERT RAMS&LCC toolkit:
  1. Automated RAMS analysis to calculate KPIs related to failure and maintenance effects
  2. LCC calculation based on RAMS KPIs



Introduction: RAMS

According to EN 50126:2005, definition of RAMS

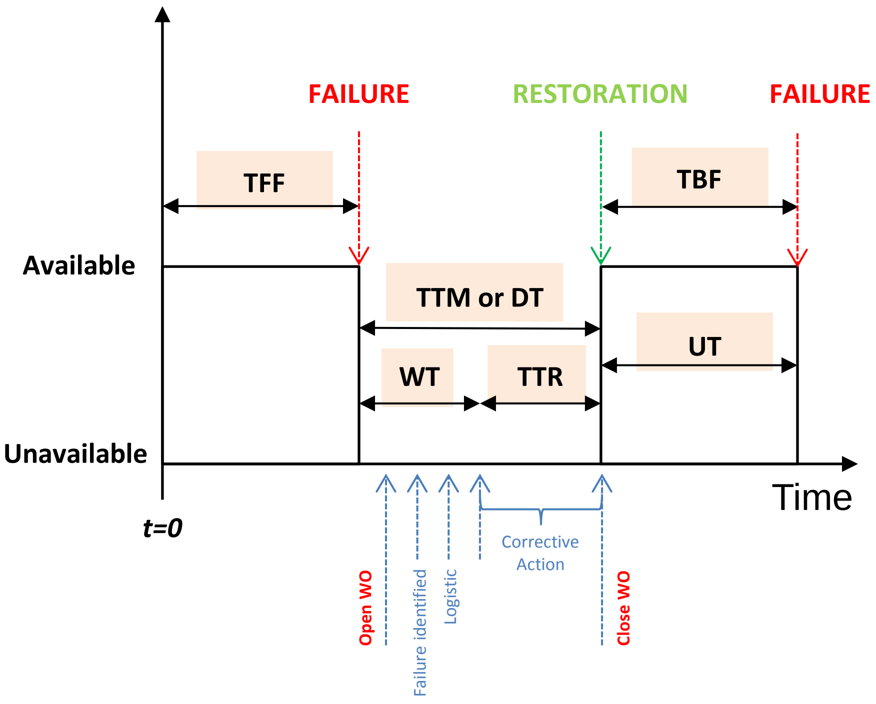
- ***Reliability*** *(R)*: probability that an item can perform a required function under given conditions for a given time interval.
- ***Availability*** *(A)*: ability of a product to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval assuming that the required external resources are provided.
- ***Maintainability*** *(M)*: probability that a given active maintenance action, for an item under given conditions of use, can be carried out within a stated time interval when the maintenance is performed under stated conditions and using stated procedures and resources.
- ***Safety*** *(S)*: the state of technical system freedom from unacceptable risk of harm.

Some examples of typical indicators for RAMS

Reliability	Availability	Maintainability	Safety
Reliability, R(t)	**Mean Up Time, MUT**	Maintainability, M(t)	Hazard Rate, H(t)
Unreliability, 1 - R(t)	Mean Down Time, MDT	Repair rate, μ(t)	Tolerable Hazard Rate, THR
Failure rate, λ(t)	Availability, A(t)	**Mean Time To Maintain, MTTM**	**Mean Time Between Safety System Failure, MTBSF**
Mean Time Between Failures, MTBF	Unavailability, 1-A(t)	**Mean Time To Restore, MTTR**	
Mean Time To Failure, MTTF		False Alarm Rate, FAR	

Introduction: RAMS

Representation of failures and different RAMS parameters for some asset.



- **TFF**: Time to First Failure (non-repairable assets).
- **TBF**: Time Between Failures (repairable assets).
- **TTM or DT**: Time To Maintain or Down Time (asset not available).
- **UT**: Up Time or available state (system in full operation).
- **WT**: Waiting Time or logistic time (system waiting for correction).
- **TTR**: Time To Restore (corrective action is taking place).

Statistical analysis

Reliability	Availability	Maintainability	Safety
Reliability, R(t)	**Mean Up Time, MUT**	Maintainability, M(t)	Hazard Rate, H(t)
Unreliability, 1 - R(t)	Mean Down Time, MDT	Repair rate, μ(t)	Tolerable Hazard Rate, THR
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Mean Time To Failure, MTTF		False Alarm Rate, FAR	

Introduction: Life-Cycle

- LCC analysis associates costs to the life-cycles of assets
- *Availability* and *Maintainability* are the most significant cost drivers in LCC analysis
- Wide range of impact on operational cost elements
- **Very important to properly model system availability and maintainability: Specially costs**

Steps in LCC modelling

1. Identify cost drivers (elements)
2. Develop the cost breakdown
3. Implement cost model
4. Identify uncertainty sources

Life-Cycle Phases (IEC 60300-3-3)	Life-Cycle Costs	Nature
- Concept and definition - Design and development - Manufacturing - Installation	Acquisition	Fixed
- Operation - Maintenance	Ownership	Variable
- Disposal	Termination	Fixed

We have focused the LCC analysis on variable costs (subject to uncertainties)

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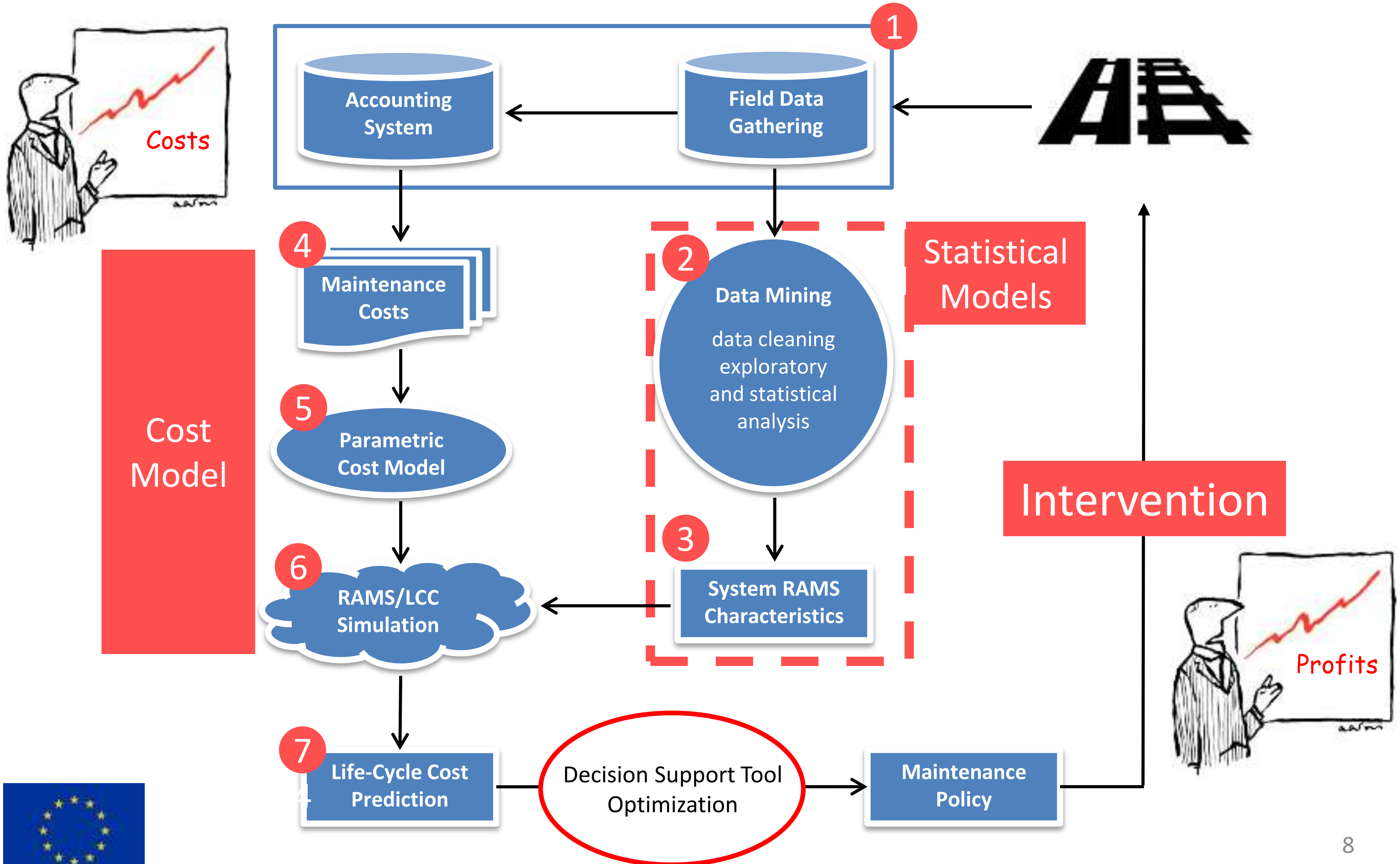
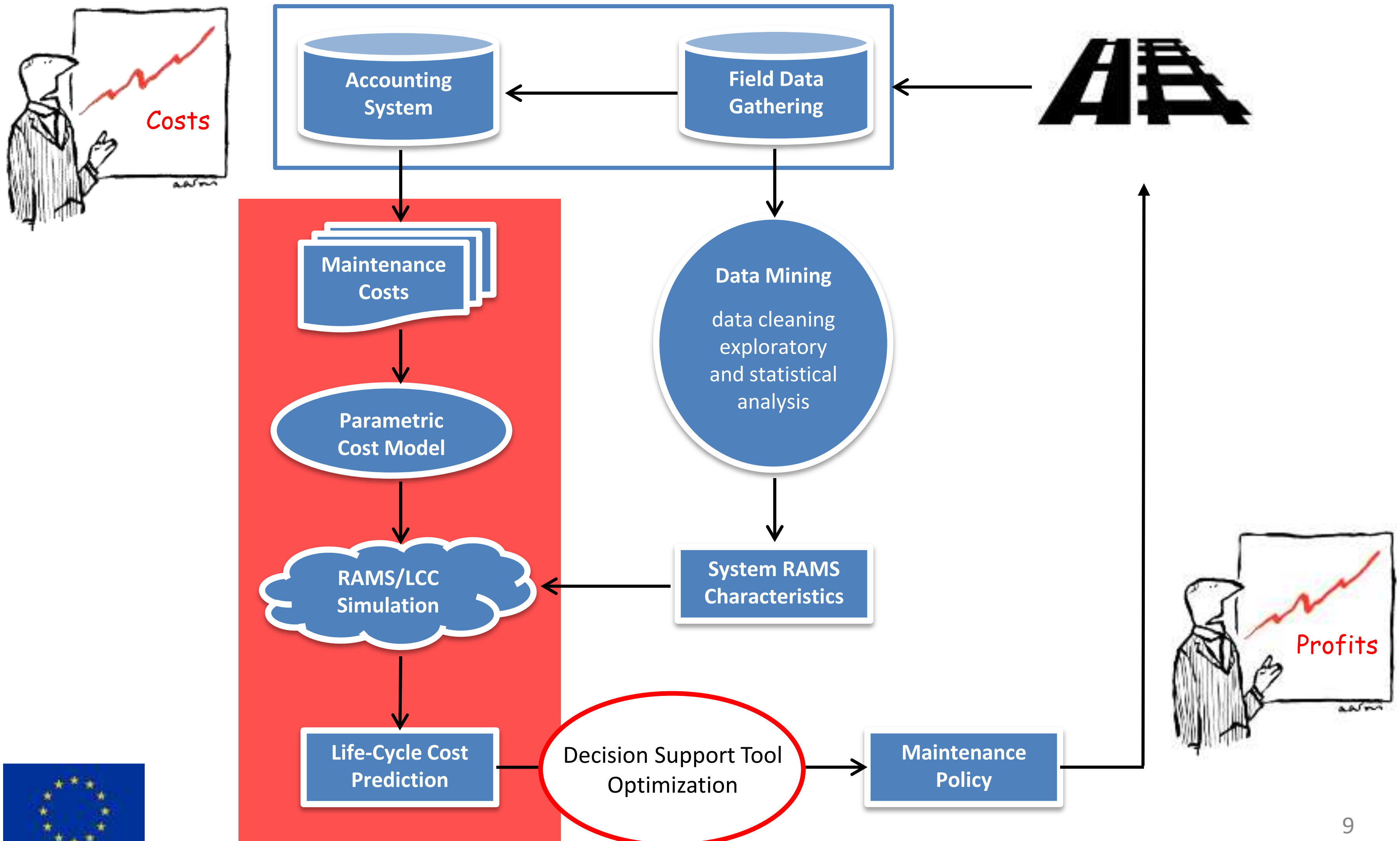
RAMS+LCC Methodology



RAMS+LCC Methodology

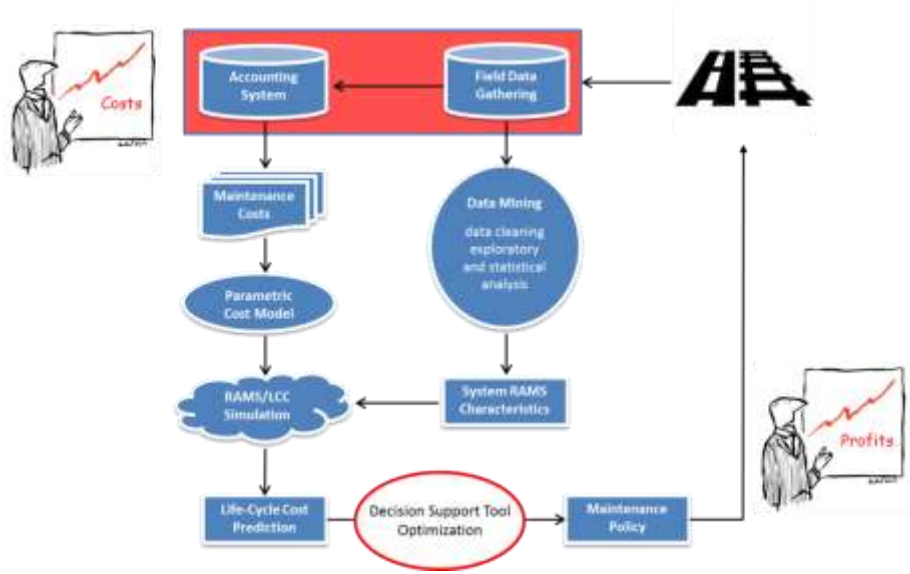


RAMS + LCC Methodology

Data processing (minimum requirements)

Work orders or maintenance database with the following information:

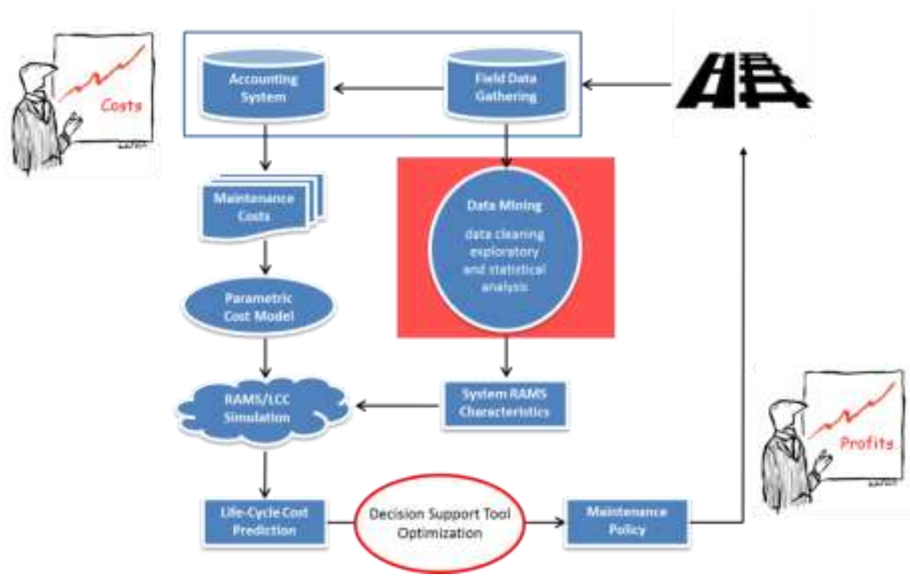
- Failure or intervention event (day, month, year, time)
- Asset/component ID (unique)
- Location information (GPS, initial/final km, track, road…)
- Construction or installation year
- Starting/Finish intervention time (better if it specifies down time, logistic time, reparation time…)
- Traffic interruption (yes/no)
- Other external factors or potential causes (better for advance statistical analysis)
- **<u>And of course: Maintenance costs</u>**



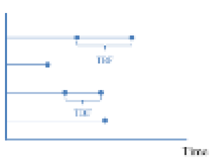
RAMS + LCC Methodology

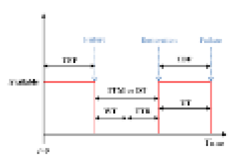
Statistical analysis

From the available statistical methods and techniques, we have selected the survival analysis or a.k.a failure time analysis. The process for every asset and intervention type is the following:

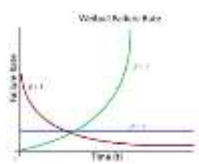


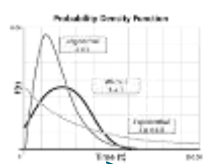
1. List and order the failure events





2. Parametric regression of data as probability distributions





3. Calculation of RAMS parameters (e.g. MTTF/MTTM)

$$MTTF = \lambda\Gamma\left(1 + \frac{1}{k}\right)$$

$$MTTM = e^{\mu+\sigma^2/2}$$

RAMS + LCC Methodology

Stochastic LCC: Monte Carlo simulation

Failure characterization

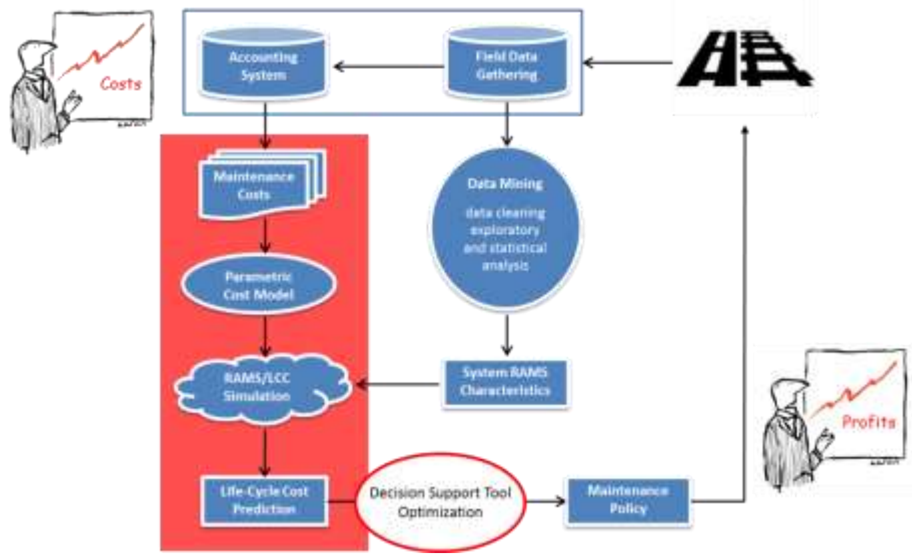
- Failure rate / Repair rate
- MTTF / MTBF / MTTM
- PDFs of failure / maintenance

Cost Model + RAMS

RAMS+LCC Simulation

Stochastic Life-Cycle Cost

- Uncertainties in LCC due to RAMS
- Relevant drivers affecting LCC
- Sensitivity of LCC
- Critical subsystems affecting LCC



$$LCC = n_s \sum_{k=1}^{periods} \sum_{i=1}^{actions} \sum_{j=1}^{components} \frac{1}{(1+r)^k} \frac{M}{MTTF_{ij}} \left\{ C_{P_j} + MTTR_{ij} \left(n_{L_i} C_L + C_{E_i} \right) \right\}$$

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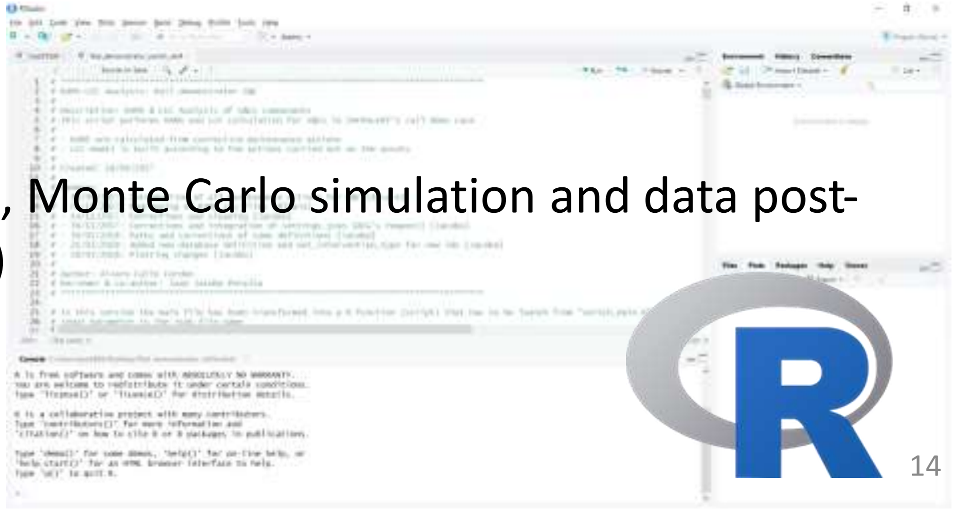
Toolkit Implementation

Computing details used to implement the RAMS+LCC toolkit:

- Implementation in R language with RStudio
- Data processing: using new algorithms and the library “data.table” with advance features similar to MySQL language.
- Survival analysis with parametric regression (Weibull and Lognormal) using “survival” library.
- Plots: frequency, events, pie-charts and boxplots using the library “ggplot2”
- 1 module for S&C (rail demo)
- 1 module for road (pavement)
- 1 Specific library for data cleaning, Monte Carlo simulation and data post-processing (original development)



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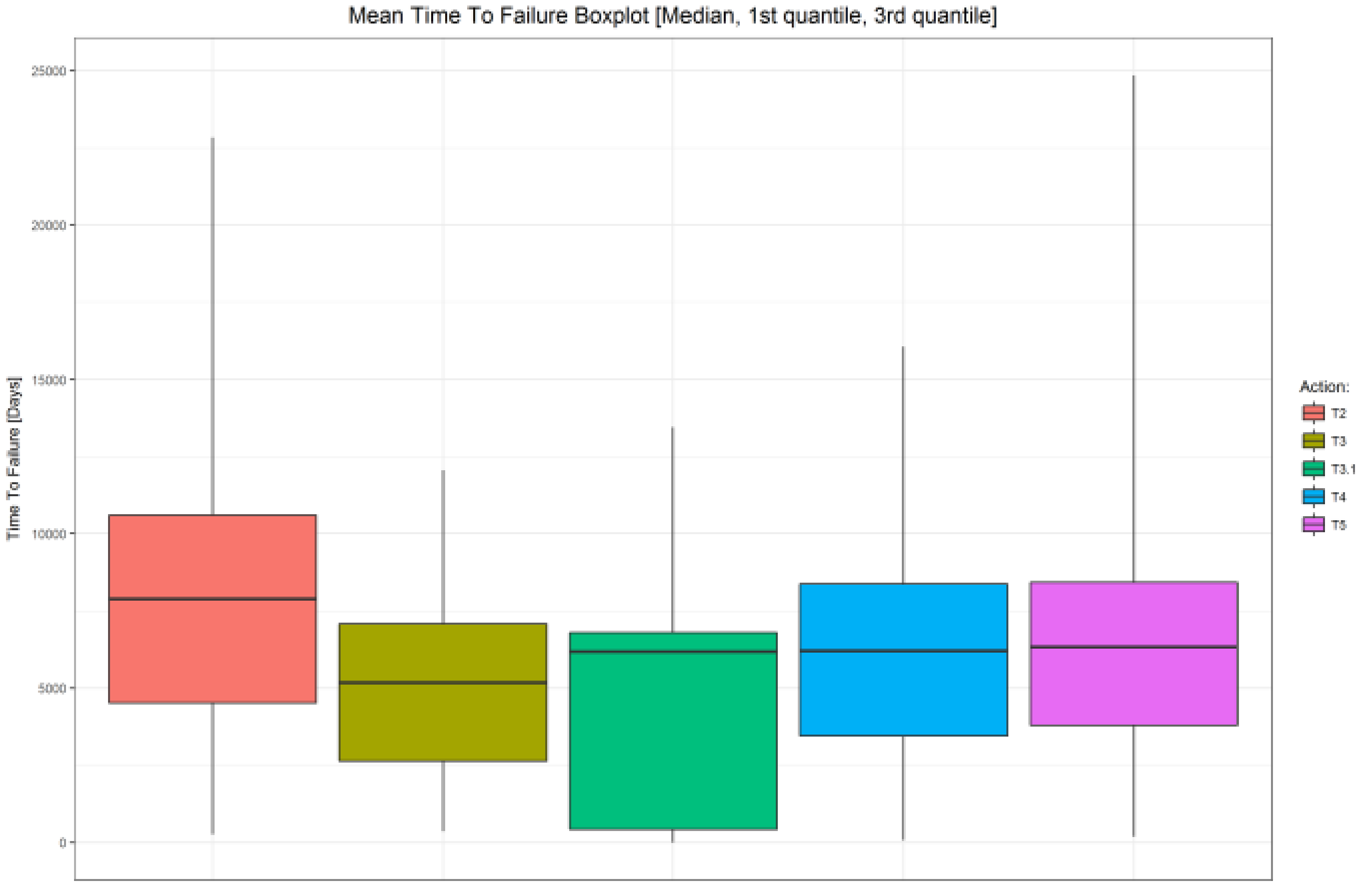
Results: road pilot

Network: Coimbra region (Portugal)

- 5 levels of interventions according to severity.
- **Assumption**: roads divided into **homogeneus sub-sections** acccording to interventions (from 100m to 25 km)
- **Statistical assumption**: after interventions all the segments are as-bad-as-old.

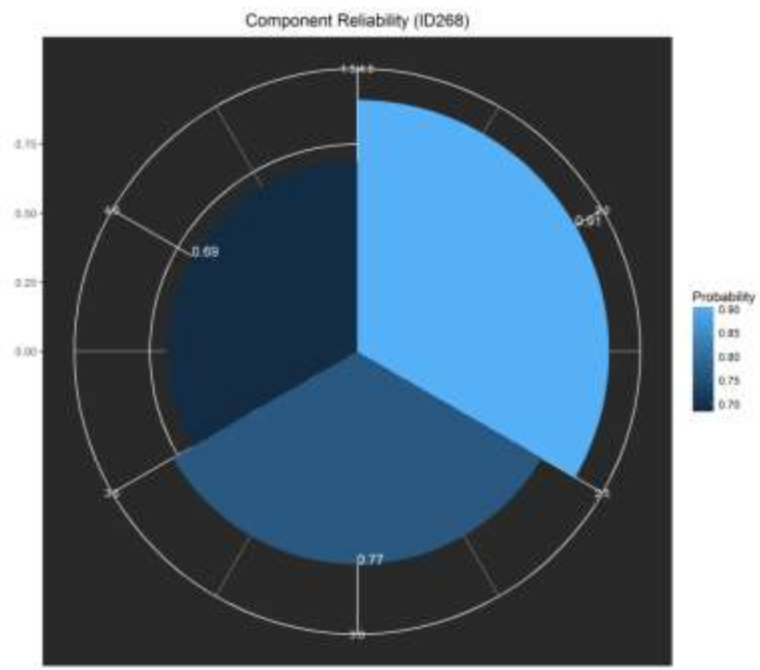
Results: road pilot

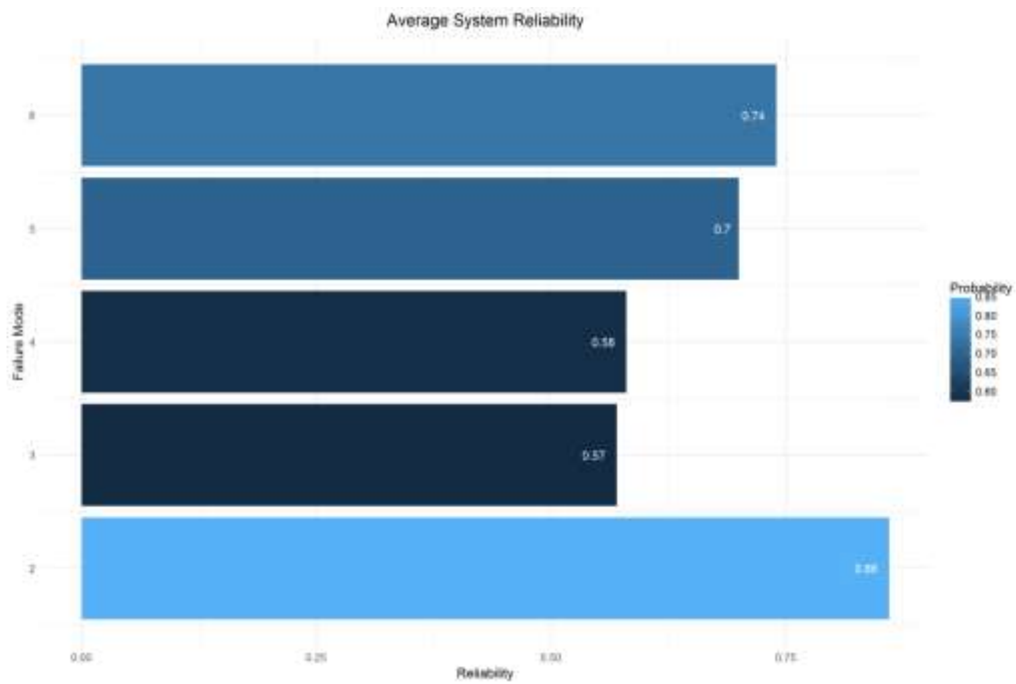
Outputs: RAMS (system level)



Results: road pilot

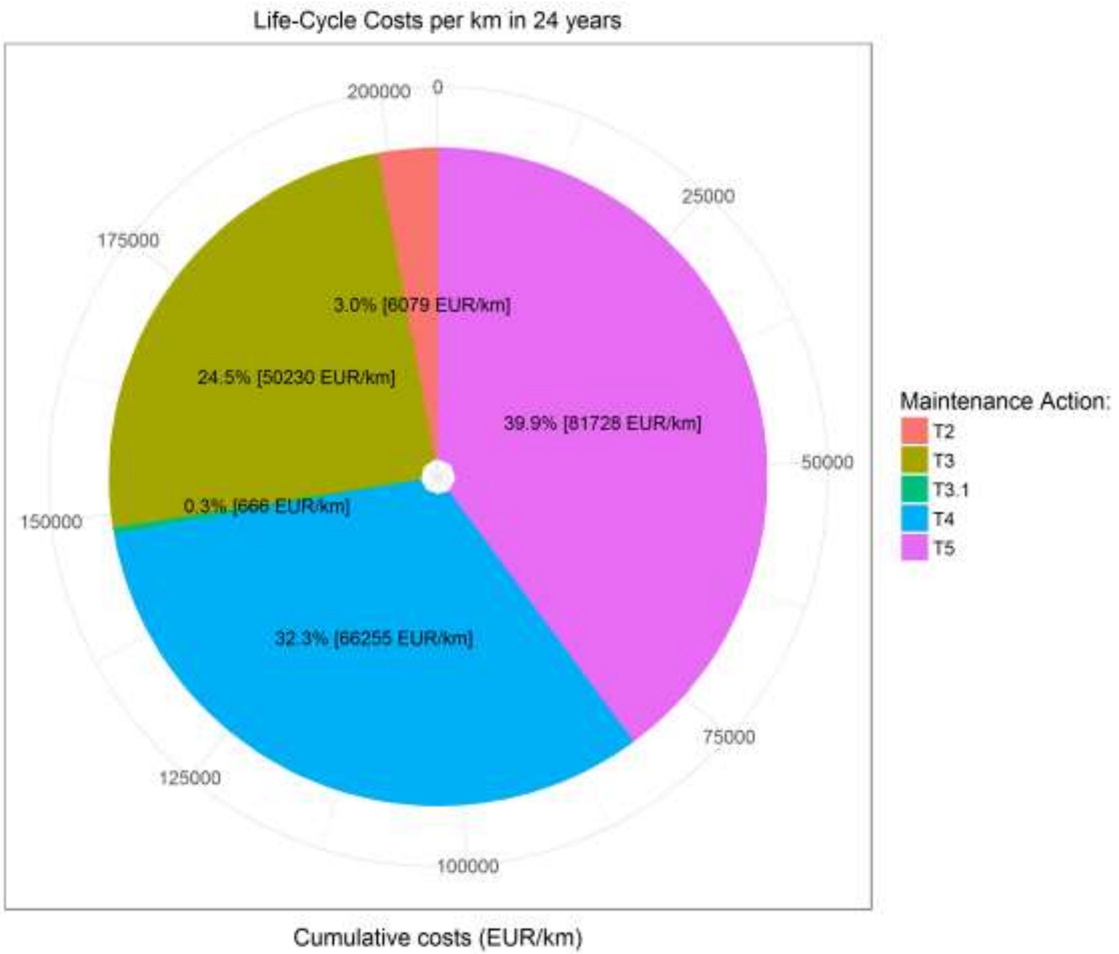
How to use RAMS outputs (1 year ahead)





Results: road pilot

Outputs: LCC for 24 years



Results: rail pilot

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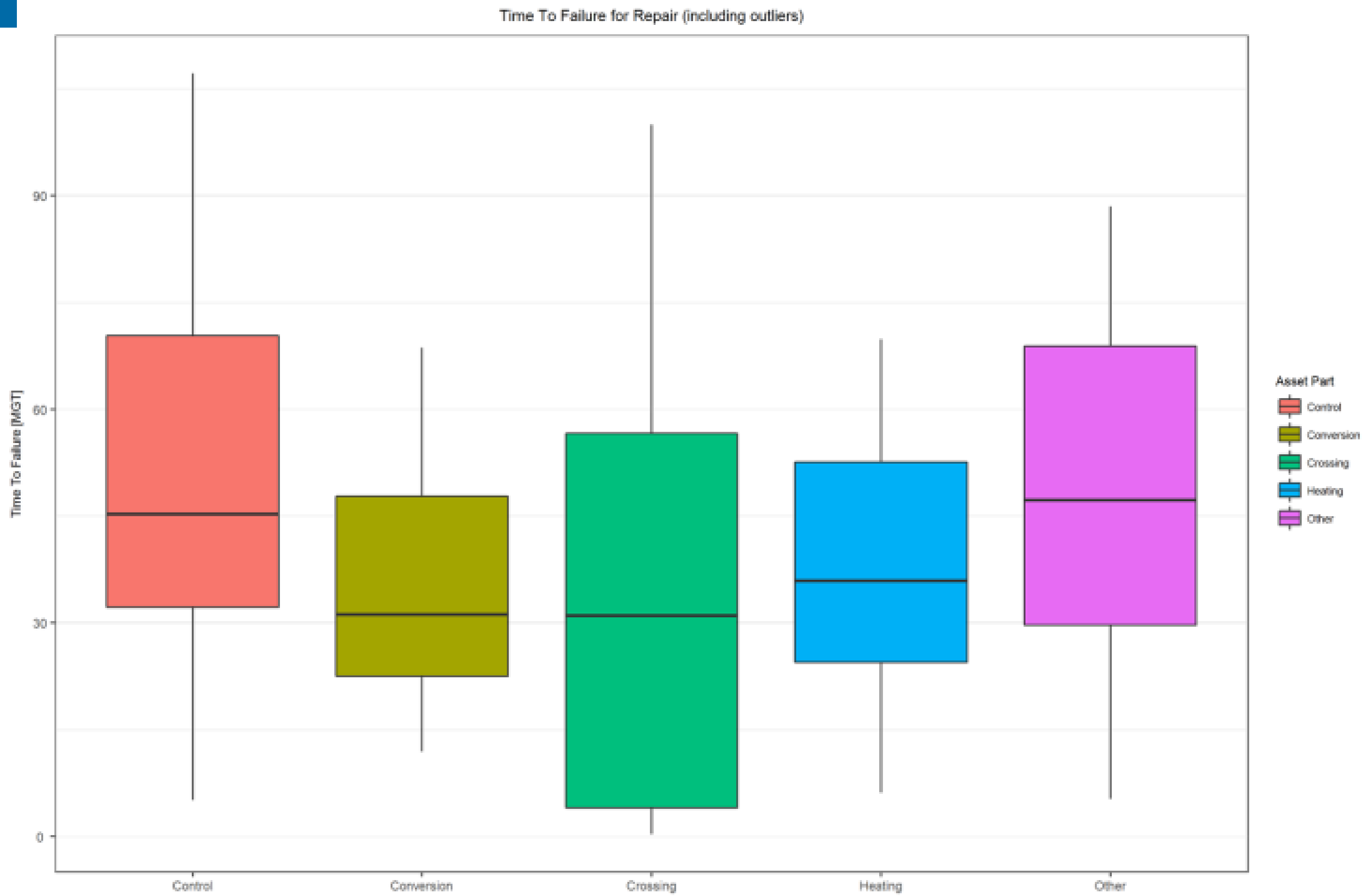
Network: Iron Ore Line (Malmbanan) in Sweden

- Study focus on **S&C**: **10% of total maintenance** costs in 2016 for Trafikverket.
- **9 Target interventions/failures modes** for **5 types of components**.
- **Statistical assumption**: after interventions **S&C are as-bad-as old state**.

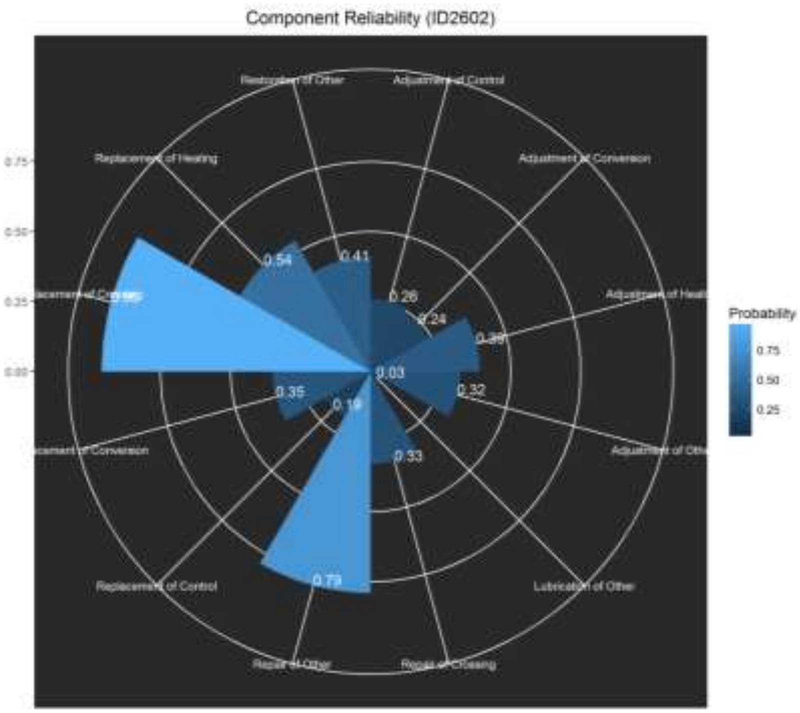
Results: rail pilot

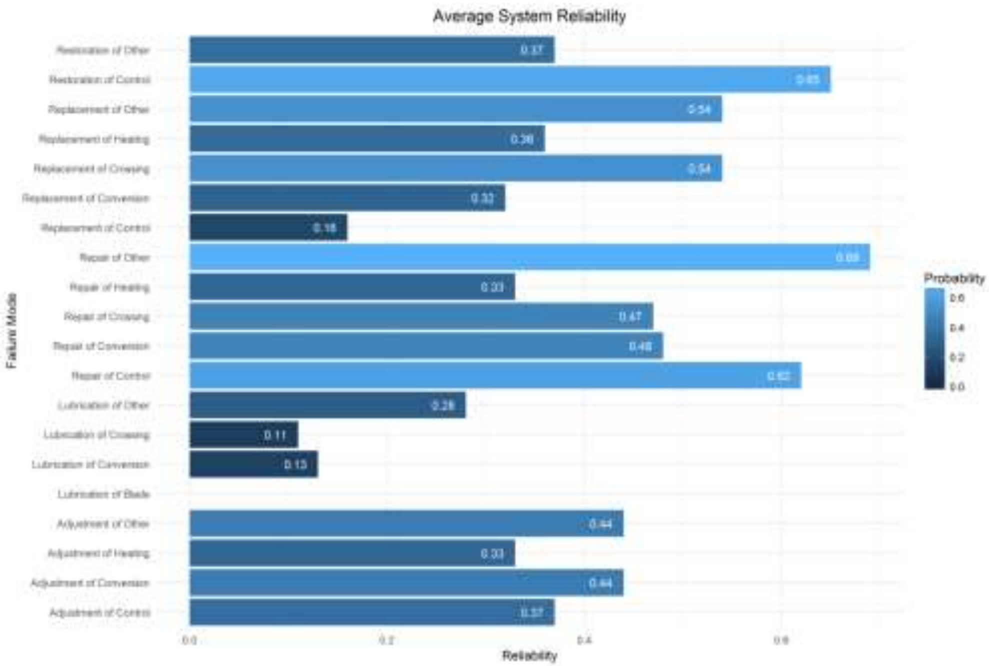
Outputs: RAMS (intervention = repair)



Results: rail pilot

How to use RAMS outputs (1 month ahead)





Results: rail pilot

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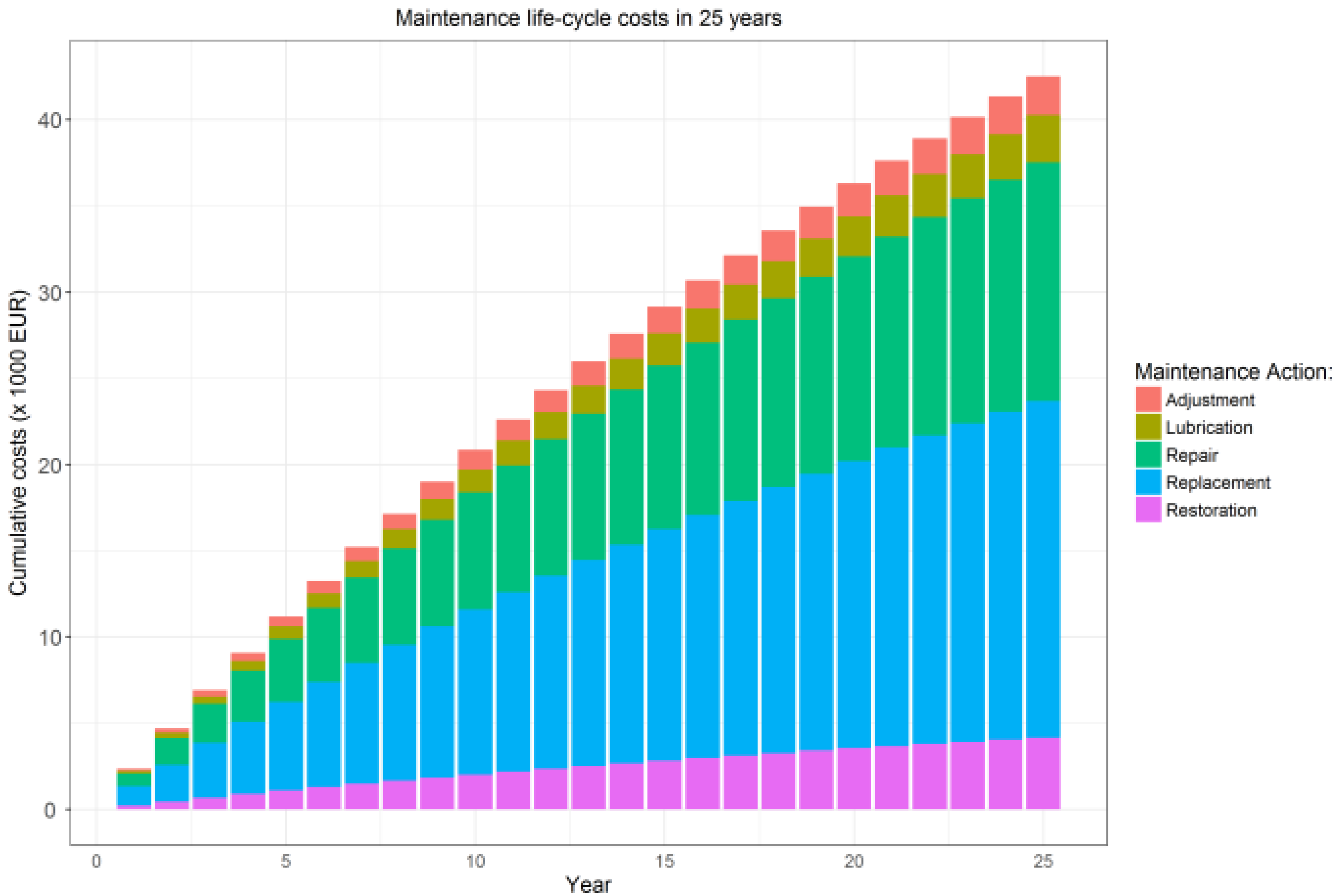
Outputs: LCC (25 years)

$$LCC = n_s \sum_{k=1}^{periods} \sum_{i=1}^{actions} \sum_{j=1}^{components} \frac{1}{(1+r)^k} \frac{M}{MTTF_{ij}} \left\{ C_{P_j} + MTTR_{ij} \left(n_{L_i} C_L + C_{E_i} \right) \right\}$$



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Conclusions & next steps

CONCLUSIONS:

- The **RAMS+LCC toolkit provides a fast way to check the reliability and LCC costs** of specific infrastructure assets using work-orders or maintenance database.
- It allows **identifying most probable/necessary interventions for individual assets or as a whole** by kind of interventions, what supports decisions about the priority of interventions.
- The case of pavement is a **new application of this technique** and LCC results have been validated and considered suitable according to expectations.

NEXT STEPS:

- Application of RAMS + LCC in **other type of assets** (both for rail and road)
- Possibility of including **covariate analysis** with an extension of the database (weather, traffic, other kind of interventions…)
- Improve the quality and variety of **cost data**.
- Explore the possibility of obtaining RAMS parameters for **multi-components towards system level KPIs**.

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