Pavement Management System

SESSION 3: Predictive maintenance

José C. Matos | University of Minho

Final Event

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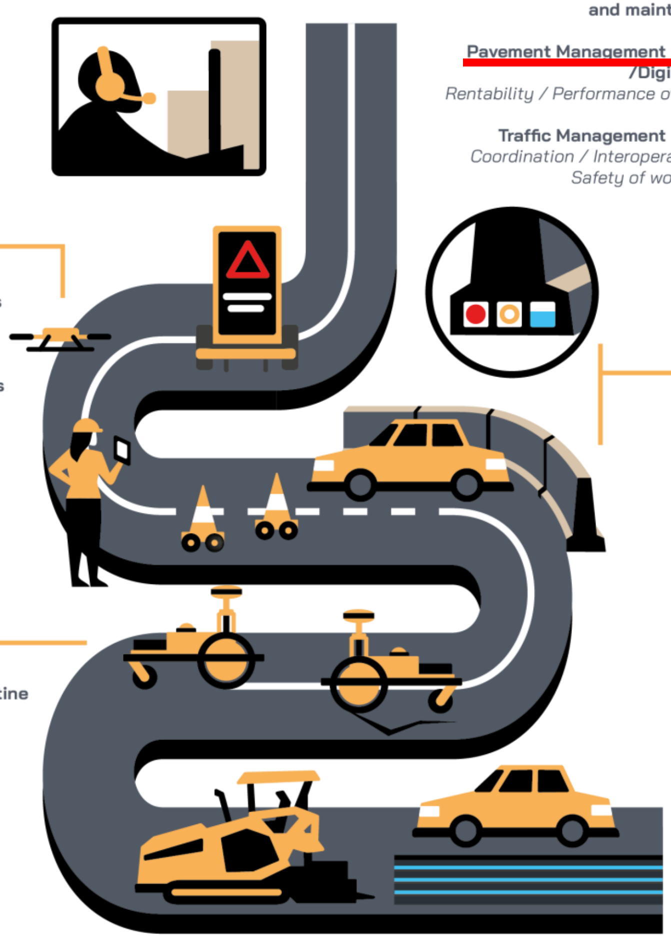
Technological areas and objectives

By focusing on the roadbed and,particularly, on roads paved with asphalt,InfraROB entails advancements across 5 strictly interrelated technological areas (TA).



TA5
Upgrading of Management Systems to ensure safer operations and maintenance

Pavement Management System /Digital twin
Rentability / Performance over time

Traffic Management System
Coordination / Interoperability / Safety of workzones

SOME KEY CONCEPTS

A **digital twin** is a virtual representation that serves as the real-time digital counterpart of a physical object or process.

Fiber Optic Sensors (**FOS**) embedded in the road pavement during construction enable long-term damage monitoring and detection.

Point location using **geo-referencing** methods allows accurate and safe navigation of the deployed robots.

Artificial intelligence (AI) applications control autonomous behaviour of equipment and achieve safer work zones.

TA4
Collaborative operation of safety cone robots and RPAS for work zone segmentation and signalling

Unsupervised monitoring of safety conditions

Alerting and signalling

TA3
Modularization of road construction/upgrade through industrial prefabrication

Multi-functional all-in-one precast concrete element
Safety barrier / Gutter and curb / Storm drain

TA2
Autonomous robotized machinery for the routine or periodic maintenance of the pavement

Potholes and cracks repair (3D printer)

Line-marking robot (cold paint)

TA1
Autonomous robotized machinery for construction, upgrade and large maintenance interventions

Road construction train
Feeder / Paver / Roller

Automated lay-down of FOS cables

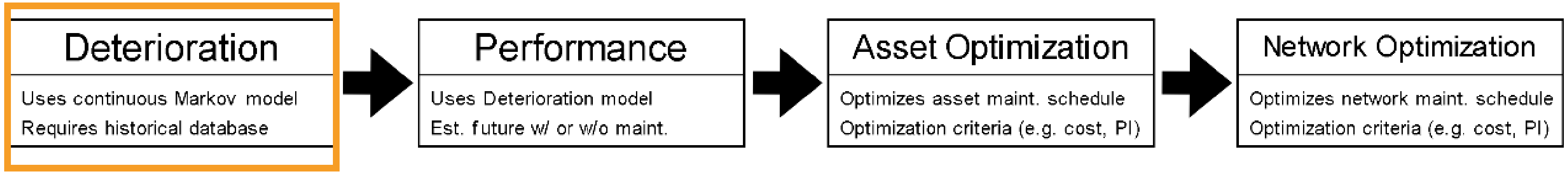
Technological Area 5 | Objective 6

TA5 Upgrading of management systems to ensure safer operations and maintenance

O6 Upgrade existing PMS applications to account for the introduction of robotics in traditional pavement maintenance.

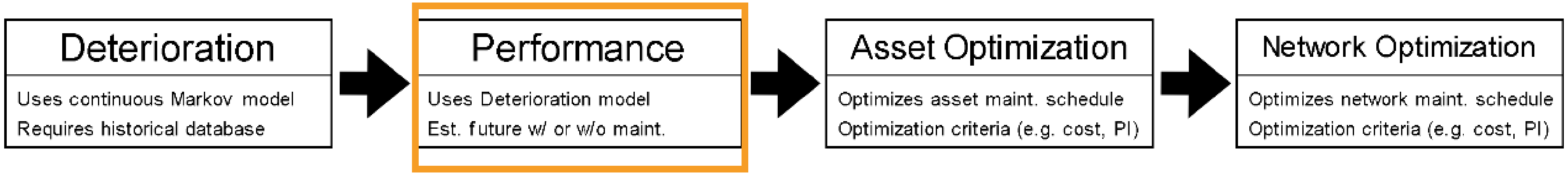
- Modelling of a robotized pavement maintenance intervention process
- Pavement maintenance services upgrading
- Cost analysis of the newly stablished robotized pavement maintenance process
- Modelling the process for decision/making on the most efficient maintenance intervention

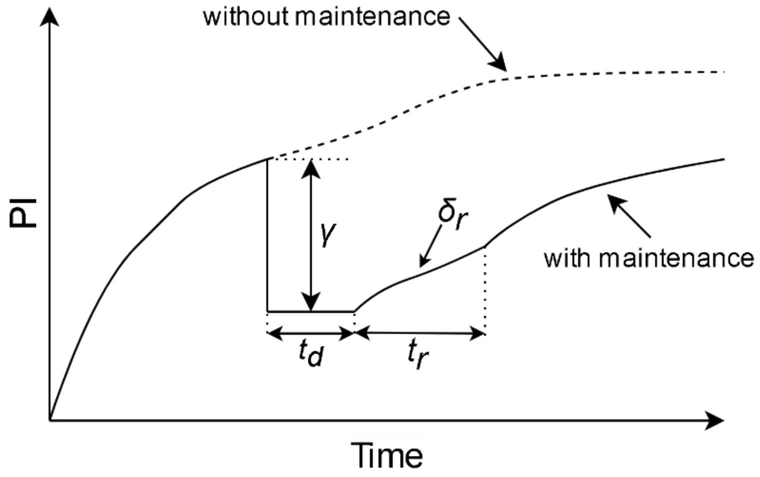
Framework and model developed to achieve the objectives



- A Continuous-Time Markov Model was implemented to predict pavement deterioration over time.
- Historical databases were utilized to calibrate and validate the model.
- Reliability was ensured by incorporating real-world data and environmental factors.

Framework and model developed to achieve the objectives





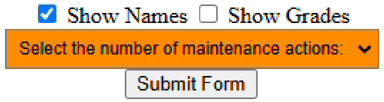
Flexible Input Framework

- The approach allows easy definition of actions without altering the software's core functionality.
- Users define the parameters for maintenance actions.

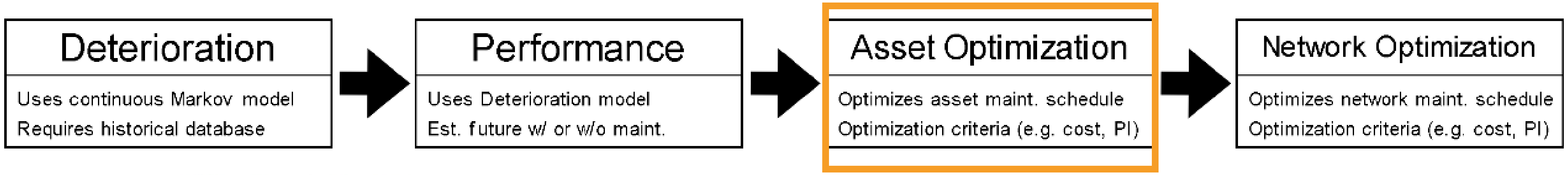
Framework and model developed to achieve the objectives

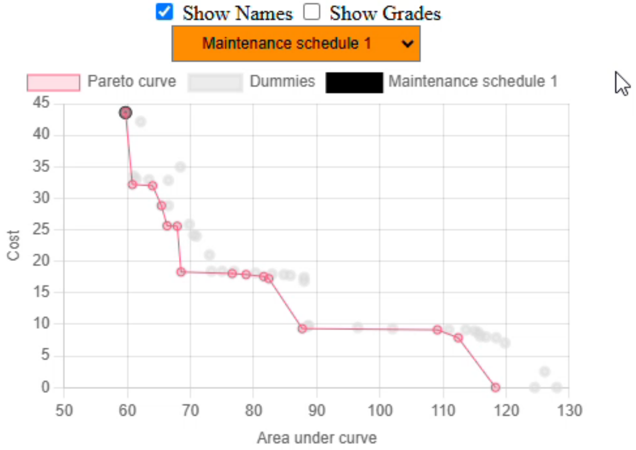
Deterioration → **Performance** → **Asset Optimization** → **Network Optimization**

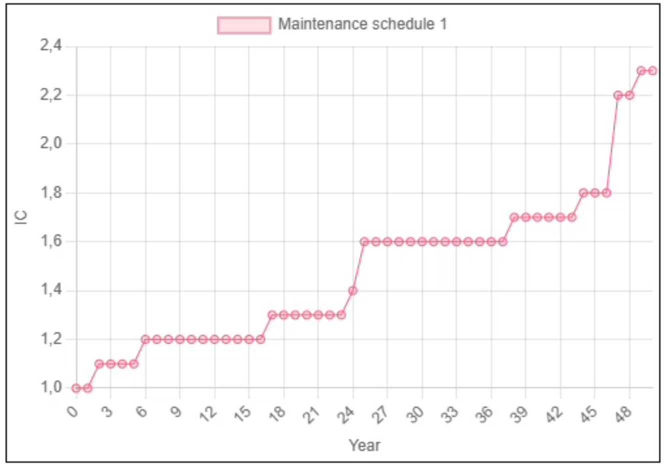
Deterioration	Performance	Asset Optimization	Network Optimization
Uses continuous Markov model Requires historical database	Uses Deterioration model Est. future w/ or w/o maint.	Optimizes asset maint. schedule Optimization criteria (e.g. cost, PI)	Optimizes network maint. schedule Optimization criteria (e.g. cost, PI)



Framework and model developed to achieve the objectives







Maintenance Schedule	
Time	**Action**
1	Milling (5-10cm) + TC + BC + TC + SC
6	Milling (>10cm) + TC + BaseC + TC +BC (5-10cm) + TC + SC
12	Milling (5-10cm) + TC + BC + TC + SC
21	Milling (<5cm) + TC + SC
32	Milling (<5cm) + TC + SC

Framework and model developed to achieve the objectives

Deterioration	Performance	Asset Optimization	Network Optimization
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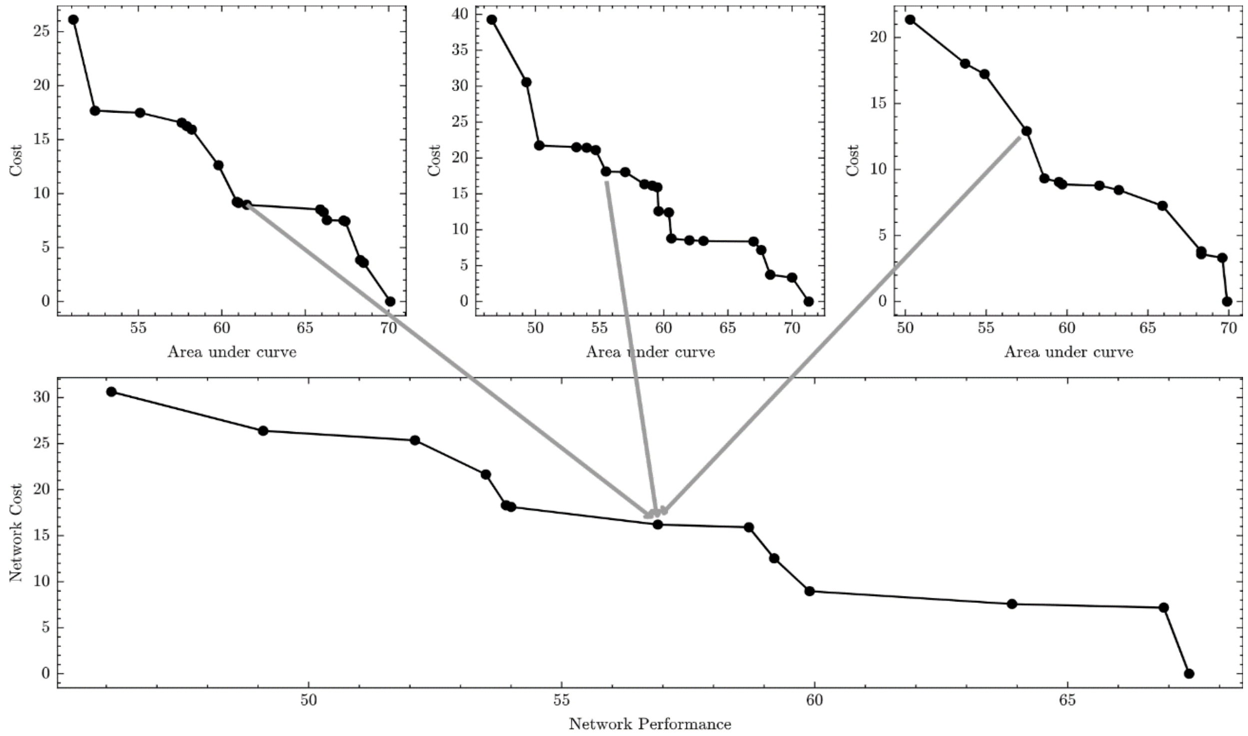
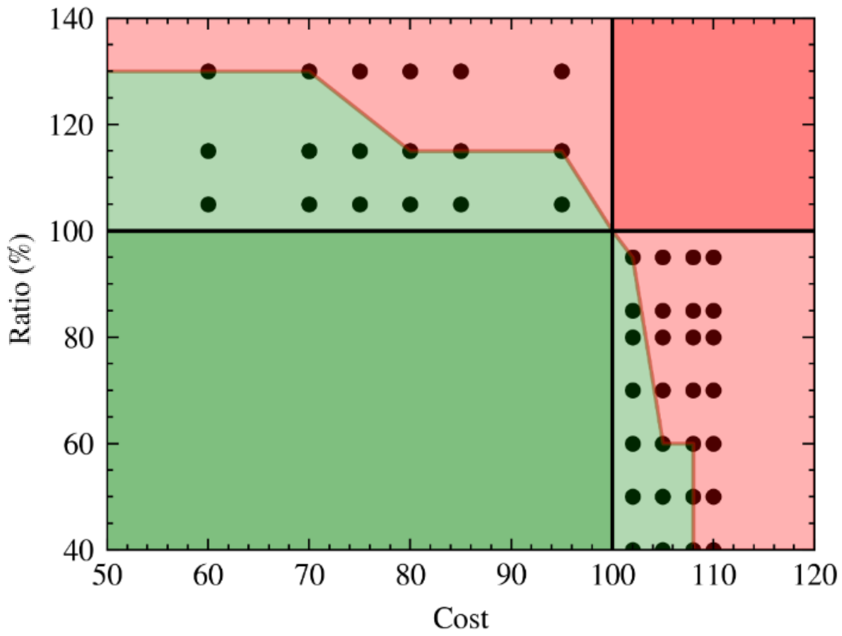


Framework and model developed to achieve the objectives

Comparative Framework



Parametric comparison analysis to assess the viability and efficiency of robotic versus conventional interventions in pavement maintenance

$$\text{ratio} = \frac{\text{Tradional}_{\text{reduction}_{\text{rate}}}}{\text{Robot}_{\text{reduction}_{\text{rate}}}}$$

Conclusions

1. **Integrated framework for maintenance optimization:** Developed a complete process integrating deterioration modeling, performance evaluation, and optimization to improve maintenance planning and decision-making.
2. **User-centric and flexible approach:** Enabled users to define maintenance actions, parameters, and scenarios, distinguishing traditional and robotic actions seamlessly within the software.
3. **Optimal maintenance schedules:** Implemented optimization models that generate cost-effective maintenance schedules while improving performance indicators and extending asset life.

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Thank you for your attention

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InfraROB

Maintaining integrity, performance and safety of the road infrastructure through autonomous robotized solutions and modularization

Project Partners